UNIT - 1

Introduction and need for ultra-performance (தீவிர செயல்திறன்) materials in building design as a substitute conventional(வழக்கமான)materials. Newer application for special performance, thermal/ sound/ moisture protection, fitting, equipment and furnishing. Properties of contemporary materials – multidimensional (பல பரிமாண), repurposed (மறுபயன்பாடு),recombinant(மறுசீரமைப்பு) ,intelligent (நுண்ணறிவுள்ள) , interfacial(இடை முகம்), transformant (உருமாறும்) etc.

INTRODUCTION :

- An introduction and implementation of super performing building materials(திறமிகு செயல்திறன்) and techniques all in terms of **energy saving efficiency** of the material, **cost efficiency**, **application feasibility**, **availability**, **vernacular characteristics, life span**, etc.
- A material is considered smart only when it contributes something to **upgrade the quality of building.**
- With all those **advancements in construction techniques** and also with the **demand of end users for the smart buildings** we as constructors and designers are ought to introduce something new and smart **to fulfill their demands and needs.**
- Smart structures and material technologies are a tool for sharing the knowledge of how various building materials can significantly increase production and profit using advanced communication, collaboration and management technologies.

Energy saving | Cost Efficiency | Application feasibility | Availability | Life Span

To understand all how and about of super performing construction materials we must study materials according to their use from very root to tip. Elements of construction where these smart materials and techniques shall be implemented are

- Foundation
- Plinth
- Beam
- Column
- Wall
- Sill
- Window
- Door
- Roof
- Parapet
- Skylights
- Finishing Works

ULTRAPERFORMING MATERIAL IN BUILDING DESIGN :

- Throughout human history, material innovation has been defined by the **persistent testing of limits**. **Ultra-performing** materials are those which are **stronger, lighter, more durable, and more flexible than their conventional** counterparts.
- These materials are important because they shatter known boundaries and necessitate new thinking about the shaping of our physical environment.
- It should come as no surprise that ultra-performing materials are **generally expensive** and **difficult to obtain**, although many of the following products are being **developed for a broad market.**

???

CHARACTERISTICS OF ULTRAPERFORMING MATERIALS :

Construction materials are said to be super performing when they

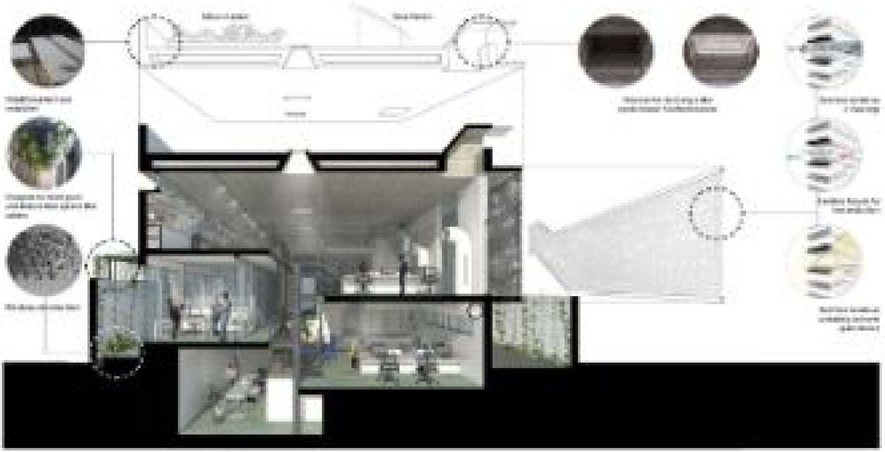
- Save overall building energy
- Make building esthetically pleasing
- Cut cost of construction
- Easily available
- Increase life span of building
- Upgrade building quality
- Make the building safe for living

WHAT ARE CONVENTIONAL MATERIALS?

- Conventional buildings use large amounts **of energy, land, water, and raw materials for their construction and operation**. They are responsible for large greenhouse gas (GHG) emissions as well as emissions of other harmful air pollutants.

WHAT ARE NON-CONVENTIONAL MATERIALS?

Bio-based (உயிர் அடிப்படையிலானது) materials involve renewable(புதுப்பிக்கத்தக்க) agricultural (வேளாண்மைக்குரிய) and forestry feedstocks (தீவனங்கள்), including wood, agricultural waste, grasses and natural plant fibers. These lignocellulosic [**plant dry matter** (biomass)] materials are composed mainly of carbohydrates such as sugar and lignin, cellulose, vegetable oils and proteins.



OFFICE OF KSM ARCHITECTS, CHENNAI

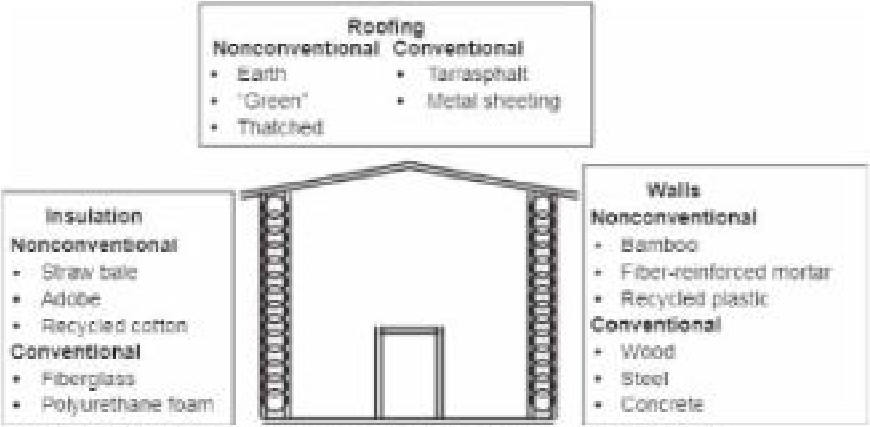


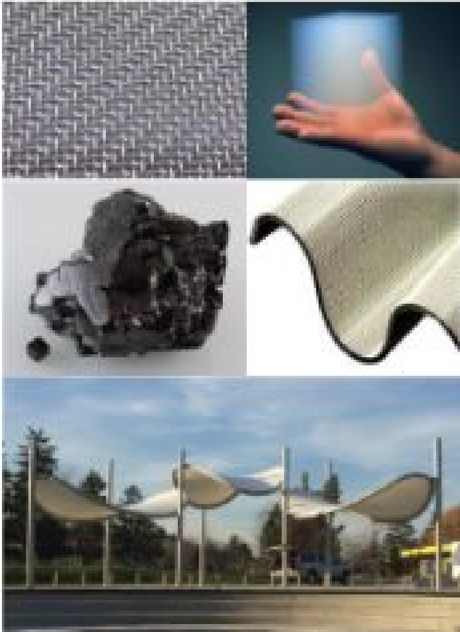
Figure 3.1 Shelter with nonconventional and conventional material examples.

LIST OF MATERIALS SUBSTITUTE FOR CONVENTIONAL MATERIALS

1. Advancements in Concrete
    - High Performance Concrete
    - Light Transmitting Concrete
    - Pervious Concrete
    - Aerated Concrete
    - Floating Concrete
2. Foamed Aluminum
3. Woven Stainless steel
4. Creative Weave Metal Mesh
5. Aerogel
6. Laminated Thermo Plastic Panels
7. Super Black
8. Banner works
9. Tension Fabric Structure

Some Super Performing Safe materials

Collapse preventing Structure
Bombproof fibre material
High pressure metal laminates
Stratified wood panels
Metafloor



Properties of Contemporary (சமகால) Building Materials :

Multidimensional
பல பரிமாண

Recombinant
மறுசீரமைப்பு

Interfacial
இடைமுகம்

Repurposed
மறுபயன்பாடு

Transformant
உருமாறும்

Intelligent
நுண்ணறிவுள்ள

PROPERTIES OF CONTEMPORARY BUILDING MATERIALS :

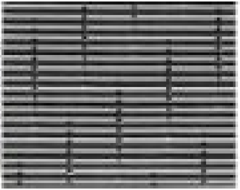
1. **MULTIDIMENSIONAL:**

- Obviously, materials are **physically** defined by **three dimensions**. But many products and buildings have long been conceived as a **collection of flat planes** which define **space** and **function** .
- **One** reason for this development is the fact that taking advantage of greater depth allows thin materials to become more **structurally stable**. **Another** reason is that materials with **Enhanced texture and richness** are more visually interesting.
- Augmented (பெரிதாக்கப்பட்டது)dimensionality will likely be a growing movement, especially considering the technological (தொழில்நுட்பம்) trends toward miniaturization(குறும்படுவாக்கம்), systems integration(அமைப்புகள் ஒருங்கிணைப்பு , and pre-fabrication (முன்கட்டமைவு).

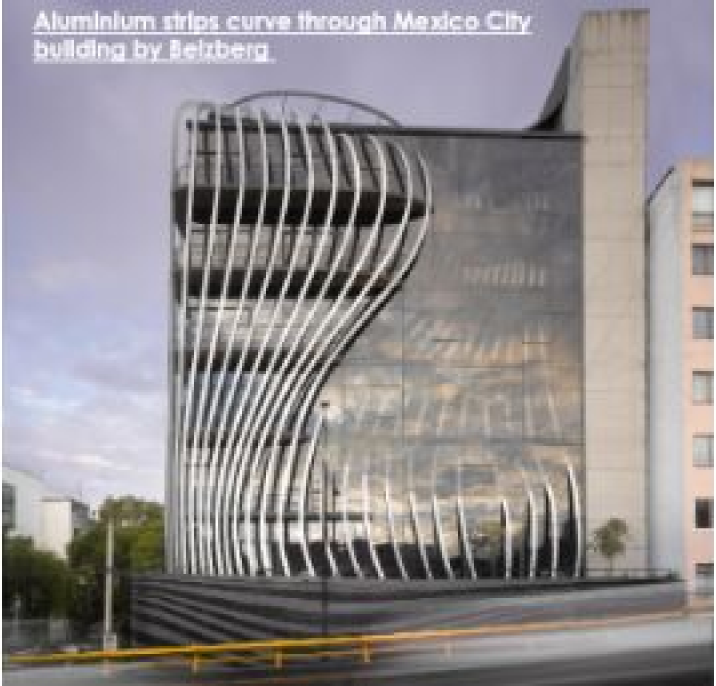
AERO (சூழ்நிலை என்பதைக் குறிக்கும் சொற்பகுதி)FORMED ALUMINUM:

- Tightly corrugated anodized aluminum sheets.
- flexible and formable.
- Variations in thickness, depth and rounded or square return edges produce five unique designs, some of which include precision-engineered perforations.
- Aero comes in a matte silver anodized finish with UV protection.
- Aero is ideal for a breadth(அகலம்) of interior applications, whether the visual impact desired is an emphasis on geometric compositions or fluid curves.
- The lightweight material is sturdy (துணிவுமிக்க) enough to be used for **wall and ceiling panels** yet is malleable (தேவைக்கேற்றவாறு அடித்து) enough to be rolled like a carpet.



Aluminium strips curve through Mexico City building by Belzberg



UNDULATING VENEER PANELS:

- Ply is a **wall panel** consisting of a **solid-wood frame** with an undulating (அலையலையாகச் செல்கிற) birch veneer of 0.4mm-thick plywood.
- This new material is so thin that it folds nearly as easily as fabric.
- The element absorbs sound well.
- Still in development is a version with **built-in lighting** and **panels** thin enough to let light pass through.
- Panels with an extra backing of sound-absorbing material are another option.

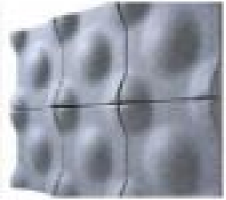
CORRUGATED (நெளி) GLASS :

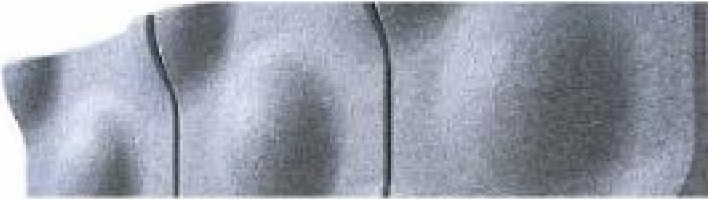
- Like structural glass channels, corrugated glass experienced its first widespread use in **industrial buildings in Europe** due to its **structural integrity** and **relative economy**, and was later adopted by the international design community for aesthetic reasons.
- The panels may be tempered(வெப்பநிலை மாற்றம்) or laminated(தகடுகொண்ட)
- The corrugations can run in a horizontal, vertical, or diagonal direction.
- The sides of the panels are flanged (தட்டையான விளிம்பு) to accommodate a variety of framing systems.



POLYESTER ACOUSTIC PANELS :

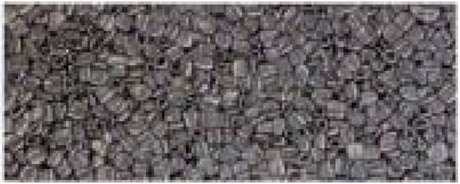
- Soundwave panel was designed to help control the sound levels in busy interiors.
- Made from recyclable moulded polyester-fibre, the undulating wave form and the felt-like material of the original Soundwave helps reduce noice levels by absorbing the mid/high frequency range.
- The material is moulded polyester fibre, the same material used in the vehicle industry to quieten the interiors of tractor cabins and cars.





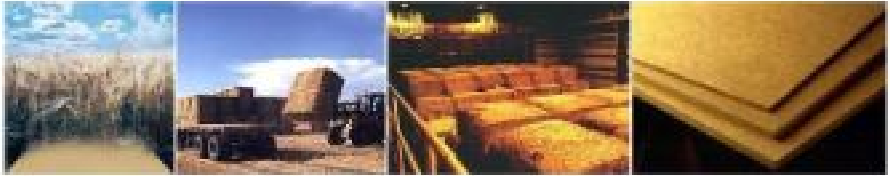
TACKABLE (பாரம் இருக்கும்) ACOUSTIC PANELS:

- Tackable acoustic panels made of porous expanded polypropylene bead(மணி) foam.
- The panels are lightweight, fully tackable, non-fibrous, structurally rigid, and have a non-abrasive surface.
- They are also Class A fire retardant.
- The panels maybe used for acoustical purposes, in commercial, educational and retail areas, and in environmentally sensitive areas
- Acoustic capabilities vary with the thickness of the panel.
- Available colors are charcoal and white.



2.REPURPOSED :

- Repurposed materials may be defined as **surrogates, or materials which are used in the place of materials conventionally used in an application.**
- Repurposed materials provide several benefits, such as **replacing precious raw materials with less precious**, more plentiful ones; diverting products from the waste stream; implementing less **toxic manufacturing processes**; and simply defying (மீறுதல்)convention.
- As a trend, repurposing is important because **it underscores the desire for adaptability in industry, as well as an increasing awareness of our limited resources.**
- While the performance of repurposed materials is not identical to that of the products they replace, sometimes new and unexpected benefits arise from their use.

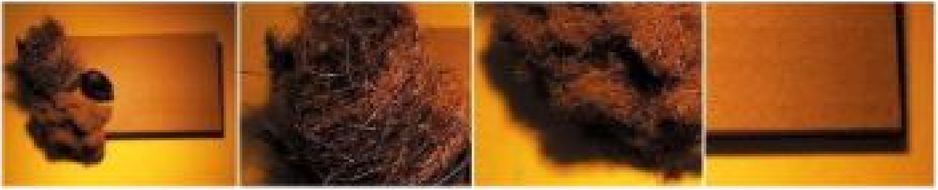


STRAWBOARD (அட்டை) :

- Made from finely-chopped wheat straw and nonformaldehyde resins, Isobord is an environmentally friendly product used in the construction of furniture, cabinetry, countertops and case good items.

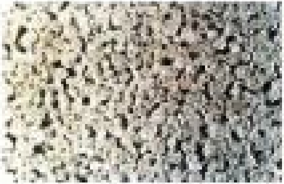
PALM FIBERBOARD (a building material made of wood or other plant fibres compressed into boards.)

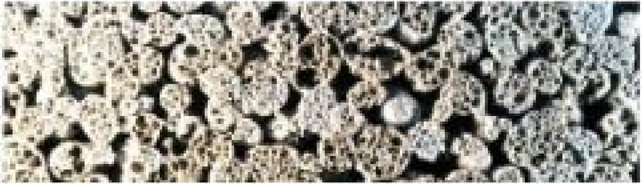
- Malaysia supplies **50 percent of the world"s palm oil**, a raw material in high demand for the **food processing and chemical industries.**
- The fibers have been found to be highly suitable for the manufacture of fiberboard for **the construction and furniture industries**.
- The residual materials are crushed and then pulped into fibrous material in a thermomechanical process. **Steam heats the fibers and then the soft raw material is ground in a refiner.** Finally, adhesive is added and the material is hot pressed to achieve the desired density and final solid form of the fiberboard.



RECYCLED GLASS INSULATION

- Insulation materials used for **sound insulation,thermal cladding** and in **fire prevention** play an important role in modern building.
- Ever since asbestos and a number of other building materials were identified as hazardous, demand has continually grown for non-fibrous building materials that do not present any risk to health.
- Researchers have developed the **fiber-free material, REAPOR**. It is waterproof, fireproof, and even resistant to acid attack.
- It **is extremely stable and at the same time light in weight, it insulates against heat and cold**, and absorbs sound. Furthermore, it is extremely environment-friendly.
- It is made of **90% recycled glass**, and can itself be recycled in its entirety. To round off its merits – it is easy to machine, to saw or to drill.
- REAPOR's basic material is the granular expanded glass Liaver, a spherical and lightweight building material made from recycled glass.





- The panels are suitable for use outdoors. Wet panels will drain freely and dry in the sun, however this may result in efflorescence where crystalline salts are deposited on the surface of the panel. Efflorescence will not affect acoustic performance. If efflorescence does occur, the salts may be removed using commercial efflorescence cleaners.

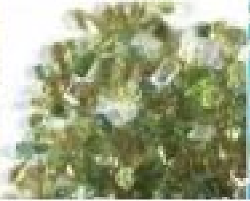
- Reapor is highly effective for commercial and industrial noise issues such as infrastructure, HVAC as well as architectural applications.

- It has already found uses in building, for example as an additive to mortar or plaster to reduce material density and thereby weight. **In the production of REAPOR, the granular expanded glass is sintered.**
- The tiny spheres of glass are heated and certain agents added. At the points where the Liaver spheres touch, extremely stable bonds or sintering necks are generated.

FRIT :

- Frit is the trade term used to describe **recycled glass** once it has been ground down into a **fine sand**.
- Generally **Frit** is seen as a midway stage in a longer manufacturing process and is normally supplied as a raw material for **making tiles or even recycled glass bottles.** However, **Frit has an aesthetic all of its own and can be used in a variety of ways which don"t involve melting or pressing**.
- makes specially sized and colored chips of recycled glass for use in terrazzo flooring, tiles, counter tops, concrete pavers, wall finishes and exposed aggregate surfaces.
- Available in a variety of colors and sizes, frit is excellent for any project seeking to **maximize green building practices and LEED criteria.**






ACOUSTICEL :

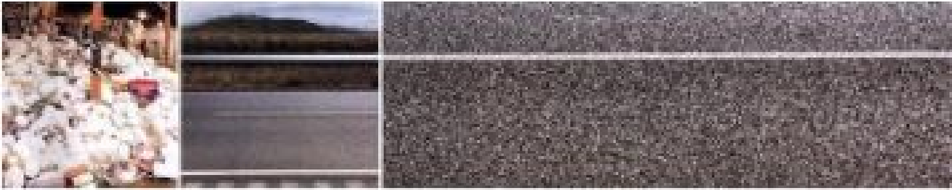
- Acousticel is an acoustic insulation material made from **100% recycled rubber**. The rubber comes from **old car tires** and is broken down into **small strips** to make this non-woven sheet material.
- The insulation is supplied in **10mm** thick rolls for floors and **1 m2 panels for walls**.

3.RECOMBINANT : (மறுசீரமைப்பு

- Recombinant materials consist of **two or more different materials which act in accord to create a product that performs greater than the sum of its parts**.
- Recombinant materials have long proven their performance in the construction industry.
- **Reinforced concrete**, which benefits from the compressive strength and fire-proof qualities of concrete and the tensile strength of steel, is a **classic recombination**.).
- The success of recombinant materials is based on their reliable integration, which is not always predictable. Moreover, recombinant materials are often comprised of downcycled components which may be difficult if not impossible to re-extract.

PLASPHALT

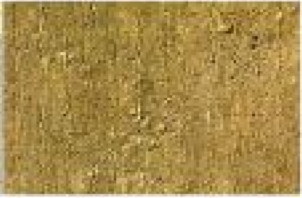
- Technology are paving the nation's roads with plasphalt - a proprietary mix of asphalt and recycled plastic.
- Though plasphalt costs 10 percent more than the straight alternative, it lasts 25 percent longer. Plus, it diverts 27 percent of all waste from landfill to highway.



FLY-ASH CONCRETE

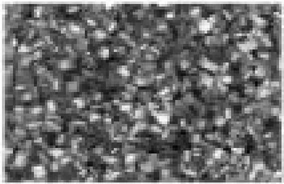
- Contents: 50% fly ash, 50% cement
- Use: Building-walls, foundations
  Fly ash, produced in abundance by coal-burning power plants, replaces a high volume of cement, which is third on the top ten list for CO2 emissions.
- Problems--Fly ash (a mixture of alumina, silica, unburned carbon, and metallic oxides) is extremely toxic, though it may be that the concrete immobilizes its impurities.





RECYCLED ALUMINUM SOLID SURFACE

- Alchemy is a new recycled solid material designed for decorative furniture and counter top surface applications.
- It is a product of beauty, strength and durability.
- Alchemy is offered in 1/2" or 3/4" thickness and is produced in custom sheet dimensions up to 36" by 120".
- The standard surface is textured. Sheets may be cut, shaped and sanded to achieve a variety of finishes from dull to high gloss, similar to other conventional solid surface materials.



STRATIFIED (அடுக்கடுக்காக) WOOD PANELS

- used externally or internally, and is generally fastened onto a metal or timber batten structure, providing a decorative finish that also acts as a rain screen.
- The surface is always 100% natural wood and has been developed to withstand the special demands of environments exposed to the elements, where it is subjected to the action of atmospheric agents such as rain, extreme sunlight, wind, snow, etc.




4.INTELLIGENT

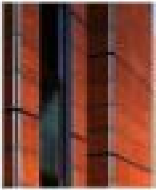
- Intelligent" is a term for materials that are designed to **improve their environment** and which often take **inspiration from biological systems**. They can act actively or passively, and they can be high-tech or low-tech.
- Many materials in this category indicate a growing focus on the manipulation of the microscopic scale.
- The varied list of benefits provided by materials featured here includes pollution reduction, water purification, solar radiation control, natural ventilation, and power generation.
- An intelligent product may simply be a flexible or modular system which adds value throughout its life cycle.

POLLUTION-REDUCING CEMENT

- A new cement which is based on magnesium carbonate rather than calcium carbonate, and absorbs carbon dioxide from the atmosphere.
- One ton of concrete made with the cement can absorb about 0.4 tons of carbon dioxide as it hardens, and tower blocks built with it could become as important as natural carbon sinks like forests and grasslands.
- The opportunities to use carbonation processes to sequester carbon from the air are just huge. It can take conventional cements centuries or even millennia to absorb as much as eco-cements can absorb in just a few months."

TERRA-COTTA FACADE SYSTEM:

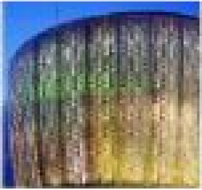
- Generally speaking, the product is a panelized brick curtain wall, and has been most visible in the recent work of Renzo Piano.
- Designers of the system recognized the fact that brick is currently used in building façades more often for its durability and weather protection than for its traditional qualities as a load-bearing material.
- The factory-produced panels consist of reinforced, stacked bricks (no grout) within zinc hardened aluminum frames which are fastened to a back-up wall that has been previously insulated and sealed. The system is designed to shed water while allowing the cavity to „breathe," maintaining a consistent air pressure between the cavity and the exterior.





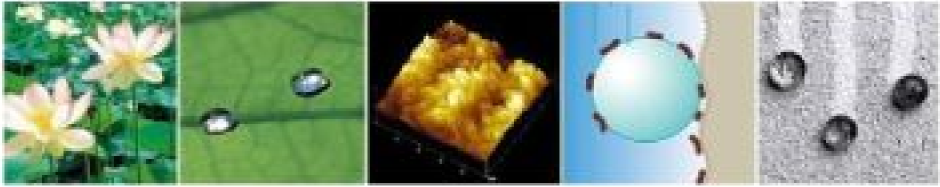
TEXLON ROOF SYSTEM :

- The Texlon Foil System is an intelligent and dynamic cladding system that has the capability to adjust its shading, thermal, and aesthetic characteristics as the sun moves across the sky, responding to specific program and climatic requirements. Made of fluoroplastic film, Texlon is self-cleaning and will not deteriorate with UV exposure. It is designed to withstand local snow and wind loads.
- Moreover, the air-filled chambers provide the roof system with its excellent thermal insulation properties. However, the system is not part of the structural system, as is the case with air-inflated buildings, where a breakdown in the air supply would cause the entire structure to collapse.


WATER-REPELLING PAINT :

- The leaves of the lotus flower are water-repellent. After a shower of rain they immediately appear dry and clean, as water runs off them like marbles off a glass plate.
- Lotusan combines the well-known water-repellent properties of silicone paints with a surface micro-structure based on the lotus leaf. This considerably reduces the contact area for water and dirt, and adhesion is also greatly reduced.
- The result is that dirt is repelled by water droplets and facades stay dry and clean - even highly stressed weather-exposed facades.



SMOG-FIGHTING PAINT

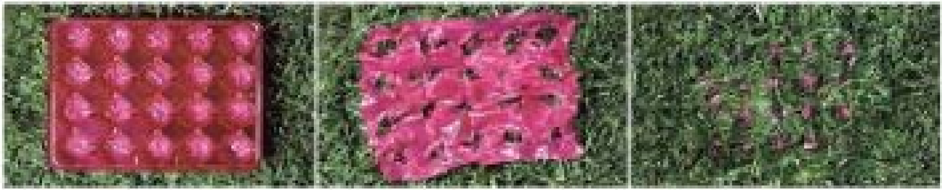
- So Called Ecopaint, the substance is designed to reduce levels of the nitrogen oxides, collectively known as the NOx gases, which cause respiratory problems and trigger smog production.
- The paint's base is polysiloxane, a silicon-based polymer.
- The acid is then either washed away in rain, or neutralised by the alkaline calcium carbonate particles, producing harmless quantities of carbon dioxide, water and calcium nitrate, which will also wash away.

5.TRANSFORMATIONAL (உருமாறும்)

- Transformational materials undergo a physical morphosis (the mode of development of an organism or one of its parts) based on environmental inducements. This change may occur automatically based on the inherent properties (இயற்கையாய் அமைப்பெற்ற) of the material, or it may be user-driven(பயனர் இயக்கப்படுகிறது)
- Like intelligent materials, transformational materials provide a variety **of benefits, including waste reduction, enhanced ergonomics, solar control, illumination, as well as interesting phenomenological (நிகழ்வு)effects.**
- Transformational products are important because **they offer multiple functions where one would be expected,** they provide benefits that few might have imagined, and they simply make us view the world differently.

BIODEGRADABLE (மக்கும்) PLASTIC :

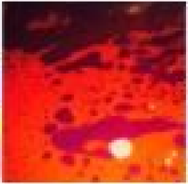
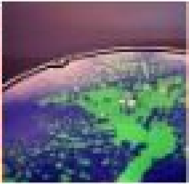
- biodegradable food packaging that's cheap enough to compete with conventional plastic.
- *A huge chunk of the 24 million tons of plastic that Americans toss each year would end up in backyard com-posters instead of landfills. And then there's the carnage that would be avoided if the plastic polluting the world's oceans dissolved rather than killing sea turtles, fur seals, and other wildlife.*
- Biodegradable plastics are **plastics that can be decomposed by the action of living organisms**, usually microbes (a microorganism, especially a bacterium causing **fermentation**.,) into water, carbon dioxide, and biomass. Biodegradable plastics are commonly produced with renewable raw materials, micro-organisms, petrochemicals (**a chemical obtained from petroleum and natural gas.**), or combinations of all three.



LIVING GLASS :

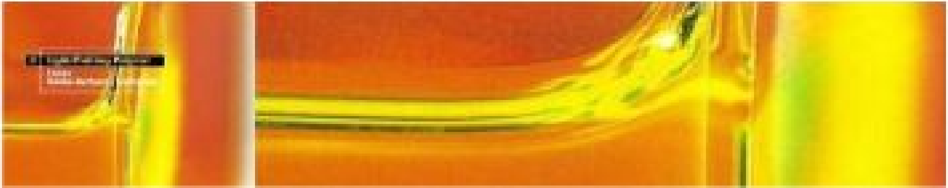
- Created a line of products consisting of layered **acrylic panels which contain a pigmented membrane**. This membrane actively transforms based on touch and vibration,enabling one to move and mix colors at will.
- This technology is currently available and -called Flex-interactive tables and is being developed in a line of floor tiles.




LIGHT-EMITTING POLYMER :

- Make way for the beginning of light-emitting plastics . Twenty years in development, conductive and semiconductive polymers (பல்பகுதிச்சேர்மப்பொருள்)are coming out of the lab.
- **Polymer emissive** displays promise **full color and high contrast** at a very **low price**. Organic LED cell phone displays fast enough to support full-motion video.

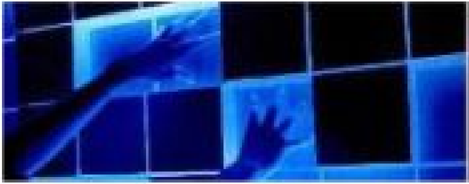


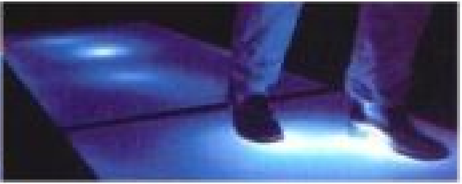
ILLUMINATED TILES :

- Rogier Sterk has developed two products which consist of illuminated tiles, Tiled Wall and Lightfloor. The **Tiled Wall** consists of **basic ceramic tiles** and **fluorescent lighting**.

- A mechanism behind each tile allows the tiles to be pressed and depressed, one at a time. A tile left untouched conceals the light behind it, except around its edges. Pushing in a tile allows the light to shine across its surface and thus to emit a reflection into the surrounding space.

- The abundance of tiles provides an opportunity to create countless patterns of light. So far the design is unique and production is limited, which means it is custom made.
- It is also posible to make a fixed light pattern, leaving out the mechanisms, making the design more affordable.





MEMORY FOAM:

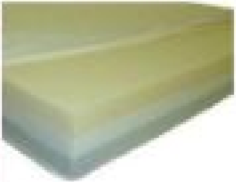
- **The National Aeronautics and Space Administration** invented the foam more than 30 years ago, when it had to develop **comfortable seating for astronauts** who had to first withstand stiff gravitational forces, then spend several days sitting in a tiny space capsule.

- The soft, flexible material, which molds to the body of the user, failed in space. But today the foam is used in a growing array of consumer products, from mattresses to bicycle seats, and now office chairs.

- "Memory foam didn"t work well in space because it"s temperature- sensitive and space is very cold, so it got very firm,".

- But for the **average desk jockey working at home or in a heated office, memory foam works well**



6.INTERFACIAL (இடைமுகம்) :

- The interface(a point where two systems, subjects, organizations, etc. meet and interact) has been a **popular design focus since the birth of the digital age**.

- **Interfacial materials, products, and systems navigate this bridge between the two realms**. They may be physical instruments which control virtual space, or virtual tools onto which physical structures are projected.

- These tools are significant because they provide unprecedented capabilities, such as time-mapping urban environments, rapid-prototyping complex shapes, integrating digital imagery within physical objects, and making the invisible visible.

Interfacial materials are also relevant because they employ the latest computing and communications technologies, and therefore are indicative of society''s future trajectory(path).

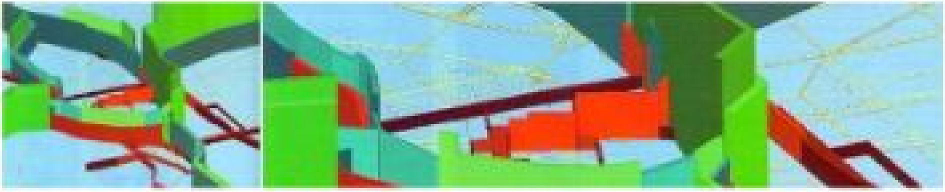
TRANSIMS :

- **The Transportation Analysis and Simulation System, or TRANSIMS**, is an integrated system of **travel forecasting models** designed to give transportation planners **accurate, complete information on traffic impacts, congestion, and pollution**.

- TRANSIMS models create a **virtual metropolitan region with a complete representation of the region"s individuals, their activities, and the transportation infrastructure**.

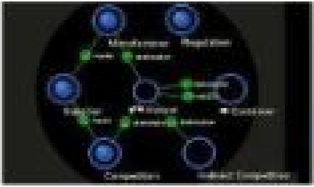
- Trips are planned to satisfy the individuals' activity patterns. **TRANSIMS then simulates the movement of individuals across the transportation network, including their use of vehicles such as cars or buses, on a second-by- second basis.** *This virtual world of travelers mimics the traveling and driving behavior of real people in the region.*

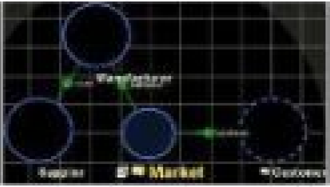
- The interactions of individual vehicles produce realistic traffic dynamics from which analysts using **TRANSIMS can estimate vehicle emissions and judge the overall performance of the transportation system.**



KNOWLEDGEMAP

- KnowledgeMap software allows users to **visualize complex systems and organize information relevant to those systems. KnowledgeMaps** can depict **business models, supply chains, environmental sustainability studies, competitive landscapes or any other type of system.**
- A KnowledgeMap can contain facts, ideas, resources or any other content.





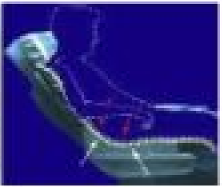
COMPUTER-DRIVEN ARCHITECTURAL SURFACES:

- Texxus creates **3D surface forms and textures for architectural, industrial & consumer products. Using advanced modelling and production software, Texxus creates surfaces at any scale**, and produces them in suitable materials using computer controlled manufacturing technology. Texxus creative design enhances the appearance, performance and value of surfaces.
- It is the first technology to have been developed to enable a new generation of consumer products with soft, flexible and lightweight interfaces.
- The design studios support architects, designers and manufacturers with a seamless group of four services:
    - **Surface Structure:** designs and manufactures large organic morphologies and freeform structures for architecture and sculpture.
    - **Surface Detail:** designs and manufactures architectural ornament.
    - **Surface Motif:** designs relief textures, patterns and motifs for industrial and consumer applications.
    - **SurfaceView:** is a visualisation and rendering service for designers using Surface products.

INTELLIGENT FABRICS:

- Today's switching and sensing technologies are basicaly rigid or semi-rigid. This results in extensive limitations on their applications and new product design becomes constrained by their physical inflexibility.
- It is the first technology to have been developed to enable a new generation of consumer products with soft, flexible and lightweight interfaces.
- By designing new fabric structures that include conductive fibres, offers lightweight switching and sensing technology that can conform to 3D shapes, is durable, cost effective, washable, wearable, and above all, desirable.



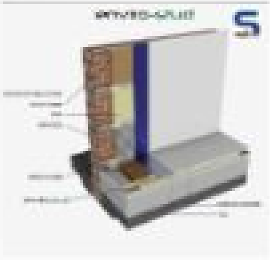
	Material	Uses	Advantages
1	High Performance Conc.	Beam	On long span structures like bridges and halls
2	Light Transmitting Conc.	Interior walls	Energy Saving
3	Pervious Conc.	Paving, Parking, Walkways	Will be permeable for water supporting water table recharge
4	Floating Conc.	Marine architecture	Will save construction cost
5	Woven Metal Mesh	Half walls, Fences, Acoustic walls	Cost and time effective
6	Aerogel	Skylight, Thermal panels	Heat resistive, transparent
7	Super Black	Paints, Varnishes and Finishes	Less Reflective, absorptive
8	Gabion work	Shading device, Landscape element	Time, Cost, Energy efficient
9	Greenwall	Vertical Gardening, Green walls	Energy conserving, Water conserving
10	Framing Truck	Flexible boundaries and Fences	Quick and versatile
11	3D Molded Plywood	Furniture, Formworks	Time Saving, Repetitive design
12	Braille Tiles	On Floor or Walls	Signage for Blinds
13	Rubber Side Walks	Foot path, Walkways	Waste managing, Time saving, Eco-Friendly
14	Natural Fiber Insulation	Thermal Panels, Blocks	Re-Used Technique I.Re purposed
15	Fly Ash Concrete	Beams, Columns, Slab	Repurposed , Provides strength to base material

Aerogel:

- Aerogel is created by drying a gel, in a high-temperature environment.
- Aerogel or "**Air glass**" is a transparent material that looks like glass, insulates better than mineral wool and is more heat resistant than aluminum.
- Aerogel is molded, giving the possibility of getting different shapes: cylinders, cubes, plates of varying thickness etc.
- Chemically, Aerogel is composed of quartz and a great deal of air, making it fragile.
- The material has many interesting properties and possible applications such as **insulation in windows and solar collectors, windows in firewalls, a component in air conditioning equipment**, etc.

- Though aerogel is technically a **foam**, it can take **many different shapes and forms**.
- Chemically, Aerogel is composed of quartz and a great deal of air, making it fragile.
- The grains of quartz are small compared to the wavelength of light, giving Aerogel good transparency properties.
- At around 750°C (1380°F), it starts to shrink and slowly collapses to a piece of ordinary quartz. Aerogel can be cut with a band saw and holes can be drilled with a metal drill. It should be noted that Aerogel is nonflammable and non-toxic

- **Architecture** :
- Aerogel is starting to become a must-have material in the insulation industry and has been used for several years in cavity injected wall insulation and insulating boards. Recently, aerogel-based plaster has been used to insulate historic buildings in Switzerland. The EMPA (Swiss Federal Laboratories for Materials Science and Technology) labs have worked with the manufacturing company Fixit AG to develop a render (insulating material) based on aerogel, which they believe will provide twice the insulation of normal renders. The use of aerogel in this way is extremely energy efficient and environmentally beneficial, as it will cut the use of fossil fuel hugely in heating.



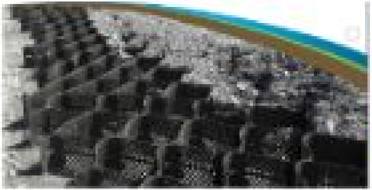
Aerogel Concrete

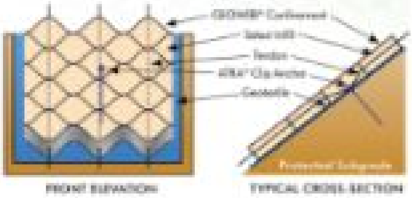
Aerogel Plaster

Geoweb:

- The GEOWEB system creates a structural soil stabilization system, protecting embankments against the negative effects of gravitational forces and loss of topsoil and vegetation.
- GEOWEB- Retaining Walls create **natural aesthetics through vegetation** in the outer fascia. The system's inherent flexibility benefits projects with challenging site conditions such as **soft subgrades, difficult access and space constraints**. GEOWEB walls may be designed as either gravity or reinforced retaining walls.
- GEOWEB® system minimizes environmental impact and offers cost-effective means for creating sustainable, long-term solutions that hold up over time.

• Reduced life-cycle costs • Environmentally friendly • Sustainability • Aesthetically pleasing





Superblack:

- **Super black** is a surface treatment developed at the National Physical Laboratory (NPL) in the United Kingdom. It absorbs approximately 99.6% of visible light at normal incidence, while conventional black paint absorbs about 97.5%. At other angles of incidence, super black is even more effective: at an angle of 45°, it absorbs 99.9% of light.

- Applications of super black are in specialist **optical instruments for reducing unwanted reflections**. The disadvantage of this material is its low optical thickness, as it is a surface treatment. As a result, infrared light of a wavelength longer than a few micrometers penetrates through the dark layer and has much higher reflectivity. The reported spectral dependence increases from about 1% at 3 μm to 50% at 20 μm.

- In 2009, a competitor to the super black material, Vantablack, was developed based on carbon nanotubes. It has a relatively flat reflectance in a wide spectral range.

TENSION FABRIC STRUCTURE:

- Transform it's" **provocative tension fabric structures are appropriate for use in entertainment venues, special events, exhibits & trade shows, or anywhere that fabric architecture is appropriate.** Made of nylon spandex, the structures offer a viable surface for any type of projection or lighting display, including front and rear projected video. It is also possible to print on the fabric via silk-screening or dye sublimation digital printing.

Figure 10: Tensile Fabric Structures

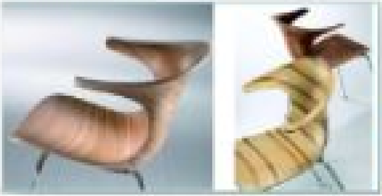
3D MOULDED PLYWOOD:

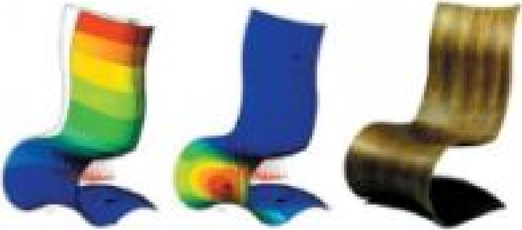
- 3D plywood panels were created in response to increased demand for products from wood which can be shaped in a mold in three dimensions, like metal or plastic. And in this case, appears wellknown problem of the anisotropy **(property of a material which allows it to change)** of wood.
- This problem is solved by patented mechanical modifications veneer.
- This product opens up new possibilities in the design of chairs, curved fronts for furniture in three dimensions, as well as veneer interior luxury cars or yachts,
- 3D plywood panels can be found in unexpected places, such as in the **interior of a luxury car, as the center console with the BMW X5**, also used in the **veneering of expensive medical equipment** such as **MRI Siemens and Loewe Opta TV whose body is veneered with exotic veneers**.

- **Future Outcomes :**

Increase the degree of possible deformation in order to obtain moldings with strong relief contours.

- One-piece plywood seat and back [5] By using three-dimensional plywood we stepped into a new world and open the possibility of producing so far hardly imaginable product. Thus once again we return to the wood its rightful place as a warm, generous, environmentally clean and renewable material.





- By development and application of **CAD/CAM software**, it is possible, prior to construction, **a software simulation of usage and analyze the behavior of the product** that will be happening in the operation. Thus we are able to advance to make certain corrections - if it turns out that the original version does not meet the predicted requirements. Therefore **the development of the product is significantly cheaper and the process of development** is shortened because the prototype selects only product that meets the functional and aesthetic criteria.

RUBBER SIDEWALKS:

- Rubber Sidewalk is a flexible, pervious rubber sidewalk system that provides a sustainable, environmentally friendly solution to cracked sidewalks. Designed to replicate the look of concrete, rubber sidewalks have a number of advantages over traditional concrete sidewalks.
- These porous rubber sidewalks utilize recycled tire rubber
- Post-consumer recycled tire rubber that is free of lead and heavy metals make up the base layer of the rubber sidewalk system. This diverts tires from landfills and reduces the need for virgin materials.
- City and public works departments are constantly faced with the public safety concerns and financial burdens posed by sidewalks damaged by tree roots, freeze-thaw, and vehicular traffic. Rubberway Sidewalks were designed with these issues in mind and not only reduce root heave and cracking, but also provide filtration and stormwater management. Rubberway Sidewalks are also non-slip in both wet and dry conditions and are resilient and ergonomic for pedestrian use.
- **Rubberway Sidewalks are a long lasting, low maintenance replacement for cracked sidewalks and for new sidewalk installation.**

RUBBER SIDEWALKS:

Creative Metal Panels :

Metal meshes have been known **as decorative and functional design** elements in architecture for only a few years.

- During the continuous product development along with ordinary use such as an fence element it became clear that metal meshes also have considerable technical advantages which are extremely relevant in the field of architecture.
- Today, the architect has a wide range of mesh samples at hand, with weaving widths up to eight meters, which allow for great design flexibility.
- Woven metallic meshes used as partition elements convey a new dimension to any space. They can be used as projection screens, and, taking into account theiracoustic characteristics, are suitable for the use in public buildings, opera houses and concert halls.

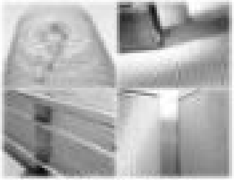


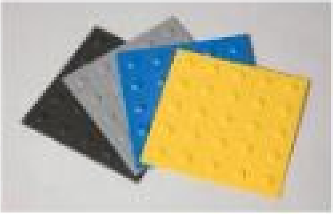
Figure 4: Woven Metal Sheets

BRAILLE TILES :

- Because it is **a factory molded item**, it conforms to the geometry of JIS standard.
- Since the thickness is 2 mm, it is unnecessary to cut and drill the installation road surface, and the occurrence of industrial waste is greatly reduced.
- Because the adhesive is MMA resin, it can be cured even at low temperature, it can be constructed even at low temperature in winter.
- It is an adhesive of the same material as the molded product, it has excellent adhesion strength and peeling hardly occurs even at the vehicle riding section.
- Excellent abrasion resistance, surface processing is hard to slip.

Applications:

- PAVEMENT SIGN PLATES FOR VISUALLY IMPAIRED PEOPLE


BANNER WORKS :

- Koryn Rolstad is a Seattle-based industrial artist who leads an integrated team of industrial designers, graphic designers, project managers and production staff in creating large-scale aerial sculptures and public art installations around the world. Known as "Banner works," her pieces dexterously cross the boundaries between sculpture and signage, art and engineering.

Figure 9: Fabric in Use as Shading Device

HIGH PERFORMANCE CONCRETE :

- Lafarge has developed a whole new family of concretes called Ductal. These concretes have high compressive and flexural strength, and their special characteristics enable the achievement of outstanding architectural feats.
- Ductal concrete incorporates strengthening fibers and opens the horizon to ultrahigh performance due to its special composition which provides it with outstanding strength, six to eight times greater than traditional concrete (under compression).
- "Fiber-reinforced" means that it contains metal fibers which make it a ductile material. Highly resistant to bending, its great flexural strength means it can withstand significant transformations without breaking.
- Ductal also comes AICMT: National conference on Alternative & innovation Construction Materials & Techniques TEQIP-II/Civil/AICMT-3 e-proceeding: | Sept-2014, All Rights Reserved MITS Under TEQIP-II 13 with organic fibers for applications with less load and for advanced architectural applications.

Figure 1: Bridge made of high performance concrete

Pervious Concrete :

- Pervious pavement is a cement-based concrete product that has a porous structure which allows rainwater to pass directly through the pavement and into the soil naturally.
- This porosity is achieved without compromising the strength, durability, or integrity of the concrete structure itself. The pavement is comprised of a special blend of Portland cement, coarse aggregate rock, and water.
- Once dried, the pavement has a porous texture that allows water to drain through it at the rate of 8 to 12 gallons per minute per square foot. Tests conclude that a square foot of Bahia sod drains at the rate of 2 1/2 to 3 gallons per minute. According to the manufacturer, this rapid flow-through ratio inspired the phrase "the pavement that drinks water."

Brainstorming Session

1.What are conventional materials ??

- Conventional buildings use large amounts **of energy, land, water, and raw materials for their construction and operation**. They are responsible for large greenhouse gas (GHG) emissions as well as emissions of other harmful air pollutants.

2 .What are the characteristics of the super performing materials??

Construction materials are said to be super performing when they

- Save overall building energy
- Make building esthetically pleasing
- Cut cost of construction
- Easily available
- Increase life span of building
- Upgrade building quality
- Make the building safe for living

3.What are the materials under multi dimensional , we looked into today??

1.Aero formed Concrete
2.Undulating Veneer Panels
3. Corrugated glass
4.Polyester acoustic panels
5. Tackable acoustic panels

4.What is the material whose name is also called air glass ??

Aerogel

5.Why is a rubber recommended in side walk ??

6.What is a Interfacial property of an ultra performing material ??

7.What is the material we saw today which is helpful to the visually impaired??

Braille Tiles


Information

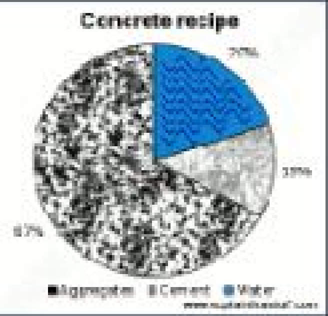
UNIT -2

Types of advanced concrete and its applications. Workability and mechanical properties, durability and reliability of advanced concrete materials. Manufacturing and application in buildings. Bendable concrete, light transmitting concrete, translucent concrete, pervious concrete, eco-cement, etc.,

Introduction to manufacture, types, properties and performance of new reinforcement (வலுவூட்டல்) materials in concrete - Aramid fibres, bio-steel, carbon (Graphite) Fibres and fibre glass etc.

Concrete :

- Concrete is the most widely-used composite(combination) material in the construction industry.
- A composite material is a combination of two materials with different physical and chemical properties.
- It is durable, weather-resistant, environmentally neutral and economically affordable.



- Concrete
  - Water
  - Aggregate
    - Fine (sand)
    - Coarse (Gravel)
  - Cement (Portland)

Do you know how as an architect you are contributing to global warming !

Global warming, the gradual heating of Earth's surface, oceans and atmosphere, is caused by human activity, primarily the burning of fossil fuels that pump carbon dioxide (CO_2), methane and other greenhouse gases into the atmosphere

Increasing threat of green house gas emissions

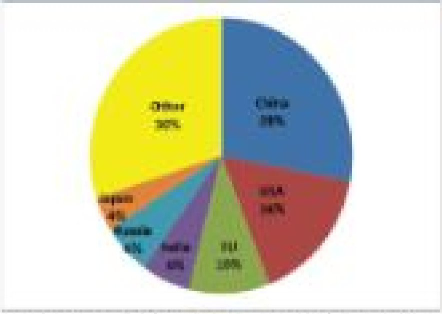
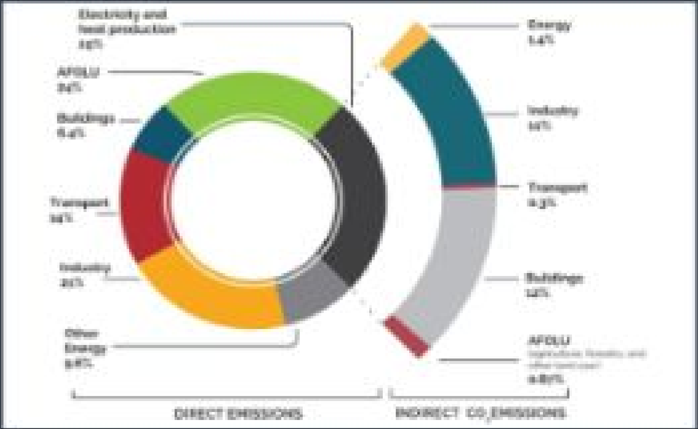


Fig.1. Breakdown of Total World Greenhouse Gas Emissions; 2015 [4]

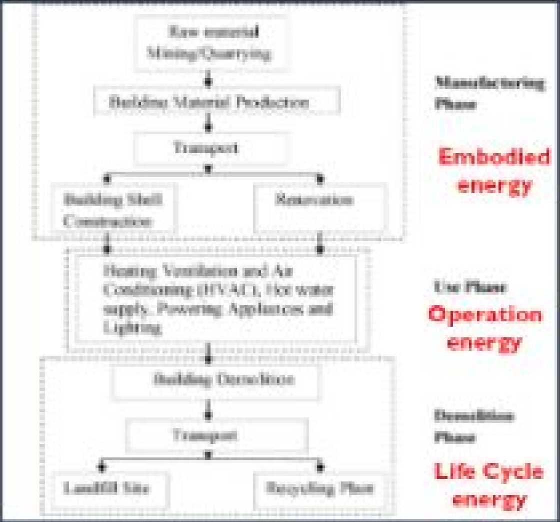
- The direct greenhouse gases CO_2, CH_4, and N_2O are naturally occurring in the atmosphere, intensive human activities have increased their atmospheric concentrations.
- It has been estimated that from the preindustrial era (i.e., ending about 1750) to 2013, concentrations of these major greenhouse gases have increased globally by 43, 152, and 20 %, respectively .



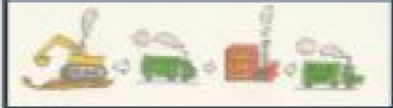
Direct and indirect CO2 emissions per sector in 2010

- Presently, energy efficiency concept is adopted to reduce operational energy requirements in the construction industry sector by selecting the suitable design and also using insulating materials.
- Reducing the global CO_2 emissions could be achieved also by selecting more sustainable materials that have lower environmental impact.

How do you choose a material ??



System boundaries for life cycle energy analysis.



-Is the energy consumed by all of the processes associated with the production of a building, from the <u>mining and processing of natural resources to manufacturing, transport and product delivery.</u>

Role of the concrete industry:

- Concrete is the most widely used material worldwide.
- As Portland cement production is known to require large amounts of energy and is responsible for the release of greenhouse gases, any effort to reduce the cement content in concrete will be beneficial.

Concrete to be the most used construction materials is mainly attributable to the fact that concrete as a whole, is made based on rocks and minerals that are mostly abundant and available in sufficient quantity everywhere.

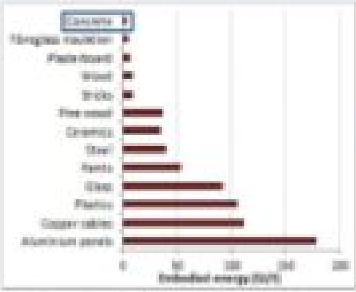


Fig.4. Comparison of embodied energy of construction materials per ton of product [9]

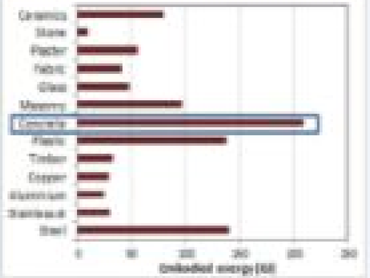
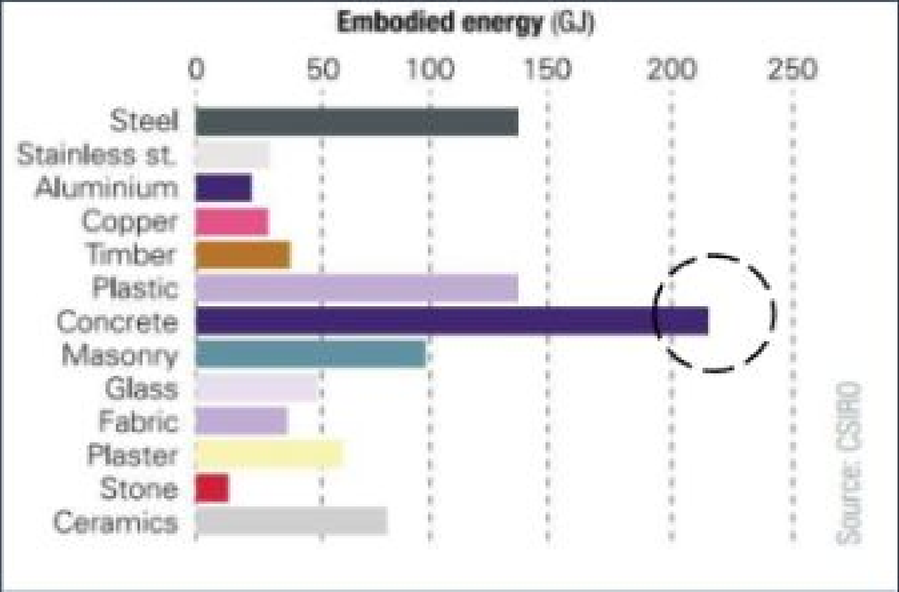


Fig.5. Embodied energy of construction materials based on their use in building [10]

Concrete :


Embodied energy (GJ)
0
50
100
150
200
250
Steel
Stainless st.
Aluminium
Copper
Timber
Plastic
Concrete
Masonry
Glass
Fabric
Plaster
Stone
Ceramics
Source: CSIRO

- Millions of tons of waste concrete are generated every year around the world due to following reasons.

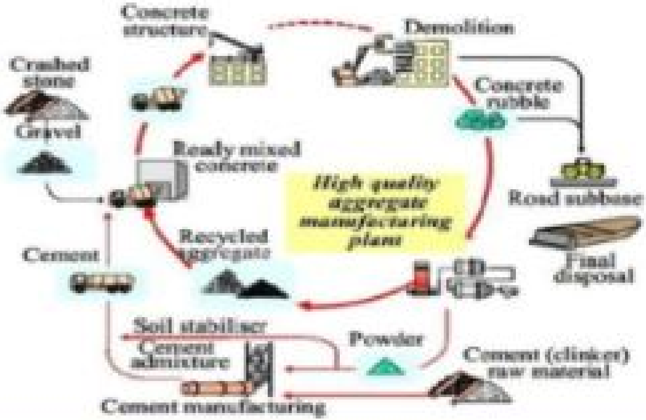
(a) Demolition of old structure.

(b) Destruction of buildings and structures due to earthquakes and wars.

(c) Removal of useless concrete from structures, buildings, road pavements etc.

(d) Waste concrete generated due to concrete cube and cylinder testing, destructive methods of testing of existing structures etc.

Process of waste concrete recycling:



Cement substitutes:

Cement is the key component of concrete that binds the other components together and gives the composite its strength. Some of the substitutes used are:

a. ***Fly ash*** (by product of coal burning power plants) Recent research has shown that it is possible to replace 100% of the cement with chemically self activated fly ash

b. ***Ground granulated blast furnace slag*** is another industrial waste product with beneficial properties

c. Probably the greatest success story in this regard is of ***condensed silica fume*** (a by product of semi-conductor industry)

- **<u>Types of Advanced Concrete and its application</u>**

High Performance Concrete
Light Transmitting Concrete
Translucent oncrete
Pervious Concrete
Aerated (காற்றோட்டம்)Concrete
Floating Concrete
Bendable concrete
eco-cement

- Types of Advanced Concrete :

- Types of Advanced Concrete :

Reinforcement

Aramid Fibre

Bio Steel

High Performance Concrete

Translucent Concrete

Autoclaved Aerated concrete

Bendable Concrete

Light Transmitting Concrete

Pervious Concrete

Floating Concrete

Ecocement

Carbon Fibre

Fibre Glass

Reinforcement

What is Ultra High Performance Concrete ?

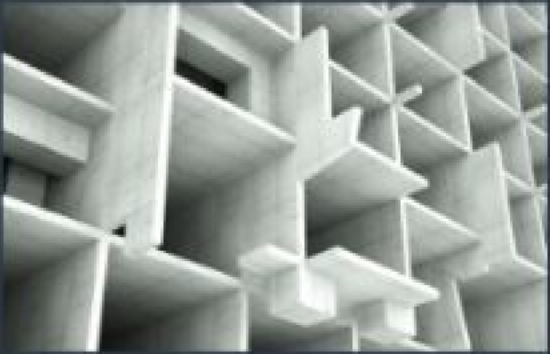
- (UHPC) is a **new class of concrete** that has been developed in **recent decades** for its exceptional properties of **strength and durability**.
- This high performance concrete can be utilized in structural rehabilitation (restoration) and **accelerated bridge construction in addition to several other applications**

1.HIGH PERFORMANCE CONCRETE

- Ductal concrete (வேலைப்பாடுகளில் அடித்துருவாக்கத்தக்க இயல்புடைய) incorporates **strengthening fibers** and opens the horizon to ultra-high performance due to its special composition which provides it with outstanding strength, **six to eight times greater than traditional concrete(under compression).**
- "Fiber-reinforced" means that it contains **metal fibers** which make it a ductile material.



- **Highly resistant** to bending, its great **flexural** strength (நெகிழ்வு வலிமை) means it can withstand significant transformations without breaking.
- A concrete which meets special performance and uniformity requirements that cannot always be achieved routinely by using only conventional materials and normal mixing,placing and curing practices.



COMPONENTS OF HPC :

The main ingredients of HPC are as follows

- Cement
- Fine aggregate
- Coarse aggregate
- Water
- Mineral admixtures (கலவையில் முக்கியமானது எனச் சேர்க்கப்பட்ட பொருள்)
  - Fly Ash
  - Silica Fumes
  - Carbon Black powder
  - Gypsum based admixtures
- Chemical admixtures
  - Improves Workability
  - Decrease in water requirement

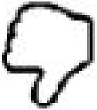
APPLICATIONS OF HPC :

- It is used for **highway pavements** due to the potential economic benefits.
- It can be used to reduce **the dead load, the deflection ,and the maintenance cost of high-rise buildings**.
- HPC is being extensively used now for the fabrication of precast pylons(towers), piers , and girders (rafters) of many long span bridges in the world.
- Concrete structures are preferable for railway bridges to **eliminate noise and vibration problems and minimize the maintenance cost.**

http://www.p-castuhpc.com.my/standard/

ADVANTAGES OF HPC

- Increase in the speed of construction
- High Workability & Pump ability
- Service life more than 100 years
- Low shrinkage & high strength
- High compressive([illegible]) strength



LIMITATIONS

- Manufactured and must be placed carefully

(allowable stress design discourages the use of high-strength concrete)

- Extended quality control is required *(High quality materials must be used)*

- Experienced supervision.

(High-strength concrete must meet high-performance standards consistently in order for it to be effective)

WORKABILITY

- Very Good
- Pumped very well
- Without segregation and voids.

SETTING TIME

- Depends on application
- Water reducing admixtures

DURABILITY

- The permeability of concrete is a key factor influencing the durability of concrete. Concrete permeability is dependent on permeability of each constituent material and its geometric arrangement.
- The permeability of cement paste is primarily related to pore structure, which includes porosity, pore size and connectivity; while pore structure is a function of the **water to - cement ratio** and **the degree of hydration.**

DURABILITY CHARACTERISTICS

- low permeability
- steel protected
- abrasion resistance

LA GRANDE ARCH , PARIS

PETRONAS TOWER

- Types of Advanced Concrete :

Reinforcement

Aramid Fibre

Bio Steel

High Performance Concrete

Translucent Concrete

Autoclaved Aerated concrete

Bendable Concrete

Light Transmitting Concrete

Pervious Concrete

Floating Concrete

Ecocement

Carbon Fibre

Fibre Glass

Reinforcement

- Transclucent concrete resins are used for transparent purpose .
- In light transmitting concrete optic fibres are used for the purpose of transmitting light.
- Especially optic fibres are use for transmission of lights

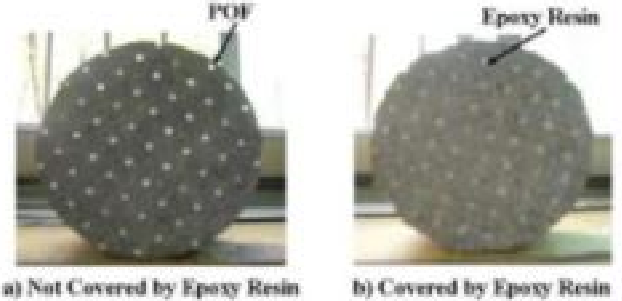


Fig. 3.3.2.1 Cylindrical concrete specimens for impermeability [1]

2.LIGHT-TRANSMITTING CONCRETE

- Light transmitting concrete(litracon) is a concrete based building material having light transmissive property.
- Light-transmissive property is mainly due to uniform distribution Optical Fibers throughout its body.It is also known to be **transparent concrete.**
- It is available **as prefabricated building blocks and panels.**

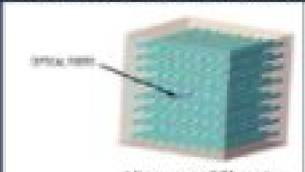



HISTORY

- In **2001** the idea of **transparent concrete** was put forward by **Hungarian architect Aron Losonzi.**
- Successfully produced **the first transparent concrete block** in **2003**,named **LiTraCon**

PRINCIPLE

- Translucent concrete works based on "Nano-Optics".
- Fibers are placed directly on top of each other.
- Fibers acts like slits and carry light through it



Alignment of fibres in a transparent concrete cube

Optical fibres

OPTICAL FIBER

- Flexible, transparent fiber made up of glass or plastic.
- It transmits light between two ends of the fiber.
- Optical fiber transmits light so effectively that there is almost no loss of light conducted through the fibers.

Al-Aziz Mosque Abu Dhabi, Light Transmitting Concrete Facade

MANUFACTURING PROCESS

- The manufacturing process of transparent concrete is almost same as regular concrete.
- Small layers of the concrete are poured into a mould and fibres are infused in it.
- Newer, semi-automatic production processes use woven fibre fabric instead of single filaments.
- Fabric and concrete are alternately inserted into moulds at intervals of approximately 2 mm to 5mm.

MATERIAL PERFORMANCE

- Concrete retains its strength
- Frost and de-icing salt resistant.
- Fire protection.
- Highest UV resistance.

APPLICATIONS :

Transparent concrete blocks is suitable for :

- Floors
- Ceiling
- Pavements
- Load-bearing walls
- Partitions wall

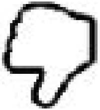
In furniture for the decorative and aesthetic purpose.

- Light sidewalks at night.
- Increasing visibility in dark subway stations.
- Lighting indoor fire escapes, in the event of a power failure.
- Illuminating speed bumps on roadways at night.

Sillhouttes of trees

Panels illuminate in different colours

- **Energy saving** can be done by utilization of transparent concrete in building.
- It has very **good architectural properties for giving good aesthetical view** to the building.



- **Very high cost about $1000/m2.**
- **Labours with technical skills are needed to use it**

- Types of Advanced Concrete :

Reinforcement

Aramid Fibre

Bio Steel

High Performance Concrete

Transclucent Concrete

Autoclaved Aerated concrete

Bendable Concrete

Light Transmitting Concrete

Pervious Concrete

Floating Concrete

Ecocement

Carbon Fibre

Fibre Glass

Reinforcement

3.TRANSLUCENT CONCRETE

- Translucent concrete is new technique different from normal concrete. Translucent concrete allow more light and less weight compared to normal concrete.
- **The use of sunlight source of light instead of using electrical energy is main purpose of translucent concrete, so as to reduce the load on non- renewable sources and result it into the energy saving.**
- Optical fibers is a sensing or transmission element, so decrease the use of artificial light , the normal concrete is replaced by translucent concrete, which has natural lighting and art design.

MANUFACTURING PROCESS :

- almost same as regular concrete.
- concrete are poured into the mould in layers.
- On top of each layers, a layer of fibers is infused.
- Fiber & concrete are alternately inserted into moulds at intervals of approx. 2 mm to 5mm.
- Adding 4% to 5% optical fibres by volume into the concrete mixture. The concrete mixture is made from fine aggregate & cement.
- 1000's of strands of optical fibres are cast into concrete.
- Smaller or thinner layers allow an increased amount of light to pass through the concrete.
- The casted material is cut into panels or blocks & polished.

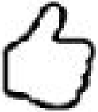
Fig Smart Translucent Concrete

APPLICATIONS :

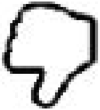
- Floors, pavements and load-bearing walls.
- Facades, interior wall cladding & dividing walls
- Partitions wall

In furniture

- Light sidewalks at night.
- Illuminating speed bumps



- Energy saving
- Good aesthetical view to the building.



- Concrete is very costly
- Skilled labour needed.

- Types of Advanced Concrete :

Reinforcement

Aramid Fibre

Bio Steel

High Performance Concrete

Translucent Concrete

Autoclaved Aerated concrete

Bendable Concrete

Light Transmitting Concrete

Pervious Concrete

Floating Concrete

Ecocement

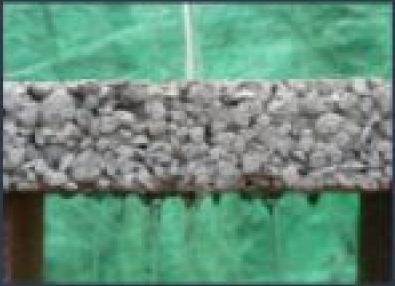
Carbon Fibre

Fibre Glass

Reinforcement

4.PERVIOUS CONCRETE:

- Pervious pavement is a cement-based concrete product that has a **porous structure** which allows rainwater to pass directly through the pavement and into the soil naturally. This porosity is achieved without compromising the strength, durability, or integrity of the concrete structure itself.
- The pavement is comprised of a special blend of Portland Cement, coarse aggregate rock, and water.
- Pervious concrete sometimes referred to as "**no-fines concrete**," is a mixture of hydraulic cement, coarse aggregate of smaller size, admixtures and water.
- Pervious concrete allows the water to percolate throuthe concrete into the sub-base and recharge th underground water level.
- Typically, pervious concrete does not contain any sand and its air void content varies between **15 and 30%**.



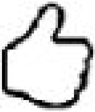
Typical composition of Pervious Concrete:

The pervious concrete help the water to infiltrate , which is help full.

- It is made by using without sand or fine aggregates.
- The pervious concrete is mainly used for pavement constructions.
- It cant be used for the construction of buildings because of its low strength.

APPLICATIONS :

Low volume traffic pavements	*Patios*	*Floors for greenhouses*	*Pavement edge drains*
Sidewalks and pathways	Artificial reefs	Fish hatcheries	Groins and seawalls
Parking areas	Slope stabilization	Aquatic amusement centers	Noise barriers
Driveways	Well linings	Zoos	Walls (including load-bearing)
Low water crossings	Tree grates in sidewalks	Hydraulic structures	Residential roads and alleys
Tennis courts	Foundations	Swimming pool decks	Sub-base for conventional concrete pavements



Environmental

- Reduces the size and sometimes the need for stormwater runoffs
- Recharges the ground water level
- Allows for the **natural treatment of polluted water** by soil filtration
- Reduces risk of flooding and top soil wash away
- Improves the quality of landscaping and reduces the need for watering

Safety

- Reduces tire noise
- Prevents glare
- Reduces hydroplaning(a situation in which a vehicle slides out of control on a wet road)and flooding

Economics

- Reduces or eliminates the need for storm sewers or retention ponds
- Increases facilities for parking by reducing water retention areas
- Longer service life and lower life cycle cost than asphalt

- Difficult in providing the reinforcements
- Frequent maintenance is required
- Compressive strength is comparatively less
- Require more time and experimental works for the construction
- It cant be used for the construction of bridges, buildings, dams and so on….

Removes Pollution

When rain soaks into the ground, not only does it re-charge, or re-fill, the groundwater and local aquifers, but it also filters out the stormwater contaminants. Instead of picking up the pollution and sweeping it into surface streams and finally the ocean, the pervious concrete and native soil filter out the heavy metals, hydrocarbons, and other pollutants passively. Studies have shown that pervious concrete systems remove 94–100% of all stormwater pollutants.

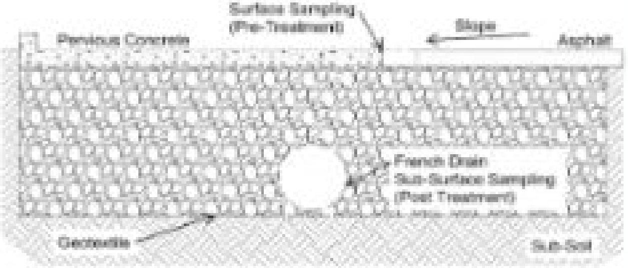


Figure 1. Schematic cross section of the Alcoa pervious pavement site

- Types of Advanced Concrete :

Reinforcement

Aramid Fibre

Bio Steel

High Performance Concrete

Translucent Concrete

Autoclaved Aerated concrete

Bendable Concrete

Light Transmitting Concrete

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Floating Concrete

Ecocement

Carbon Fibre

Fibre Glass

Reinforcement

5.AUTOCLAVED AERATED CONCRETE :

- Autoclaved aerated concrete ("AAC"), is one of the many building products being touted as "green" or "environmentally friendly."
- Developed in Sweden in the 1920s in response to increasing demands on timber supplies, AAC is a lightweight manufactured building stone.
- Comprised of all natural raw materials, AAC is used in a wide range of commercial, industrial, and residential applications.
- AAC now accounts for over 40% of all construction in the United Kingdom and more than 60% of construction in Germany.

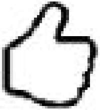



MANUFACTURING PROCESS:

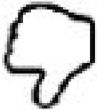
- AAC is a precast product manufactured by combining silica (either in the form of sand, or recycled fly ash), cement, lime, water, and an expansion agent - aluminium powder, and pouring it into a mould.
- In structurally reinforced AAC products like lintels or roof panels, steel rebar or mesh is also placed in the mould.
- Once added to the concrete, the aluminium powder reacts with the silica, resulting in the formation of millions of microscopic hydrogen bubbles. The hydrogen bubbles cause the concrete to expand to roughly five times its original volume.
- The hydrogen subsequently evaporates, leaving a highly closed-cell aerated concrete, then cut into which are further steam and pressure cured in an autoclave.

TYPES OF BLOCKS

STANDARD BLOCKS
CORED BLOCKS
JUMBO BLOCKS
U BLOCKS



- AAC reduces additional material use and minimizes waste and pollution.
- AAC Has High Thermal Efficiency
- AAC Reduces Noise Pollution and Improves Indoor Air Quality.
- AAC Structures Are Well-Suited to Withstand Fires, Earthquakes, and
- Other Natural Disasters.
- Easily workable



- Scarcity of Manufacturing Plants
- Familiarity with Product

APPLICATIONS :

- Residential Constructions
- Commercial Constructions
- Institutional Constructions
- Hotels and Hospitals
- Multistoried Constructions
- Industrial Constructions

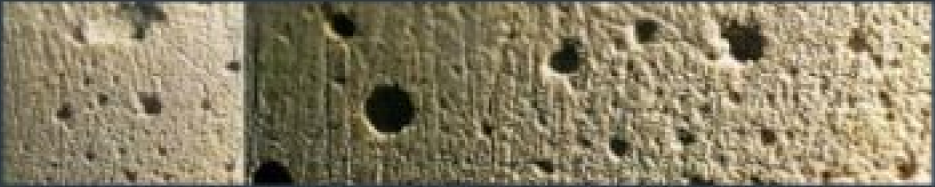
Other properties :

- low weight results in easy handling and rapid laying by the mason
- Pest Resistant
- Water resistance
- Speed construction
- does not rot, warp and rust

- Types of Advanced Concrete :

6.FLOATING CONCRETE:

- By replacing **sand and gravel** with tiny **polymeric spheres**, **University of Washington** materials scientists have created a concrete stronger than traditional concrete but so light it floats in water.
- The cement used is somewhat similar to Ferrocement but, instead of steel wire mesh, **aluminium wire mesh is used possessing a light weight** than regular chicken mesh making an innovative type of "**Aluminicement**"(Carbon fiber mesh can also replace the aluminium mesh as it is the best among the light weight but strong meshes available).
- Pozzolanic Portland Cement (PPC) reinforced with **polypropylene fibers**, for increasing the binding among particles was used.



WATER PROOFING AGENT

- For this reason a water proofing substance is required
- One of the major requirements of **floating concrete** is it should not have **any leakage** through it. The porosity of the concrete mortar should almost be equal to zero.

PROPERTIES

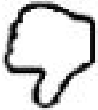
- Excellent Acoustic Performance:
- Light Weight
- There is Lightweight advantage for the structure design, leading to savings in supporting structures and foundation.
- Earthquake Resistant
- Weather proof, termite resistant and fire proof.

WORKABILITY

- Products made from lightweight concrete are lightweight, making them easy to place using less skilled labor.
- The bricks can be sawed, drilled and shaped like wood using standard hand tools, regular screws and nails. It s simpler than brick or concrete.

INSULATION:

- Superior thermal insulation properties compared to that of conventional brick and concrete, so reduces the heating and cooling expenses.
- In buildings, light-weight concrete will produce a higher fire rated structure. brick, the lightness of the material increases resistance against earthquake.



LIMITATIONS:

- Cannot be construct in flooded and earthquake prone area.
- Skilled labour is required.
- Doesn't have much compressive strength then conventional concrete but can be overcame by using nano-technolgy .

- Types of Advanced Concrete :

Reinforcement

Aramid Fibre

Bio Steel

High Performance Concrete

Translucent Concrete

Autoclaved Aerated concrete

Bendable Concrete

Light Transmitting Concrete

Pervious Concrete

Floating Concrete

Ecocement

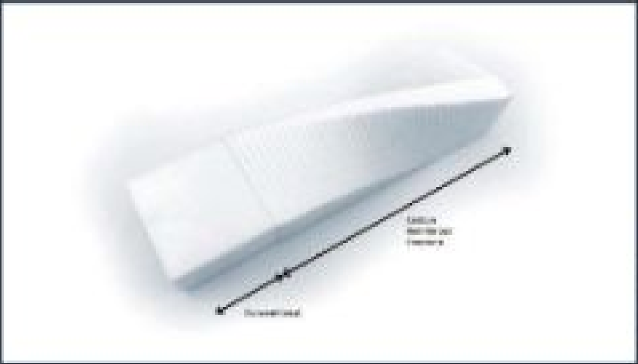
Carbon Fibre

Fibre Glass

Reinforcement

7.BENDABLE CONCRETE

- Conventional concretes are almost unbendable.
- This lack of bendability is a major cause of failure under strain.
- It has been a pushing factor in the development of an elegant material namely, bendable concrete also known as Engineered Cementitious Composites (ECC.)
- Capable of exhibiting considerably enhanced flexibility.



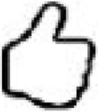
MATERIALS

- CEMENT
- SAND (FINE AGGREGATE)
- SUPER PLASTICIZER
- FLY ASH
- PVA FIBRES
- WATER

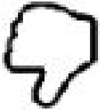
APPLICATIONS

- Earthquake resistance building
- Concrete canvas(USED IN MIITARY AREAS)
- For roads & bridges: (NO NEED OF JOINTS)

- The flexible concrete has the ability to bend like a metal.
- It is more Stronger, more durable, and lasts longer than conventional concrete.
- It has a self-healing property that is it can heal itself by using carbon dioxide and rainwater.
- It is not brittle like a glass.
- It is more resistant to cracking.
- It does not emit that amount of harmful gases as compared to conventional concrete.
- The flexible concrete is approx. 20-40 percent lighter.
- The use of steel reinforcement is reduced and can be eliminated.
- It reduces the cost of the project.
- It can be used as precast concrete.



LIMITATIONS:



- It has a high initial cost as compared to conventional concrete.
- It requires skilled labor for its construction.
- It needs some special type of materials which can be difficult to find in some areas.
- Its quality depend upon the material used and the condition under which it is made.
- Its compressive strength can be lesser than the conventional concrete.

- Types of Advanced Concrete :

8.ECOCEMENT PROCESS :

- Ecocement, a coinage associated with Ecology and Cement, is a new type of cement produced from municipal incineration ash, sewage sludge and additional limestone and clay.

There are two types of Ecocement,

- Ordinary type
- Rapid hardening type.

Ordinary type Ecocement

- Ordinary type Ecocement, having virtually the same performance as Ordinary Portland cement, can be applied to reinforced concrete structures or a variety of other uses including as soil stabilizer or solidifying agent for sewage sludge.

Rapid hardening type Ecocement

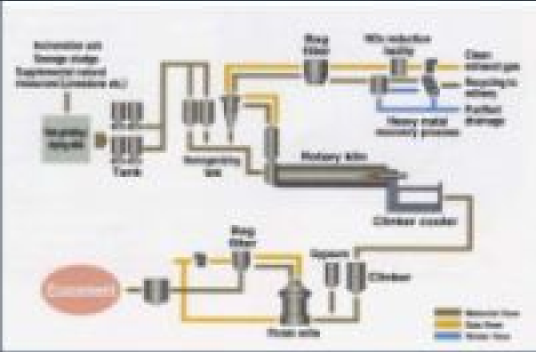
- Rapid hardening type Ecocement can be used in the non reinforcing concrete market, taking advantage of its rapid hardening property, which strengthens quicker than high early strength Portland cement.

Ecocement process:

- produces cement appropriate for a variety of uses due to its stable quality,
- makes contaminants in municipal waste harmless,
- is an excellent Zero-Emission production process.
- is equipped with a perfect environmental protection system including heavy metal recovery and flue gas purification.
- prolongs the life of precious landfill sites and greatly contributes to the Resources Recycling Society.

Process flow

- To prevent cement clinker(residues) from heavy metal contamination, heavy metals contained in municipal incineration ash are maximally separated from the chimney gas stream in the form of metal chloride.
- Separated metal chlorides are concentrated and purified to the extent that they can be reprocessed as useful metals in refineries.
- In this way, the Ecocement process saves precious metal resources and at the same time, realizes enhanced environmental protection.
- Traces of residual heavy metals are melted into clinker, but are harmless because they are all fixed in clinker crystals



- Types of Advanced Concrete :

Reinforcement

Aramid Fibre

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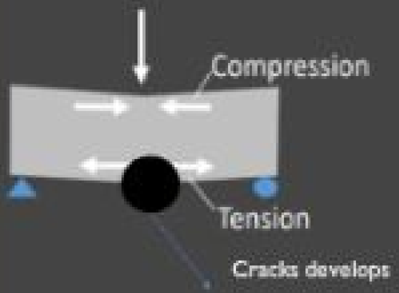
Fibre Glass

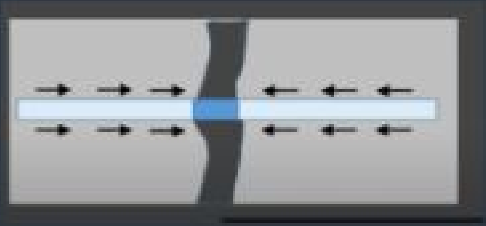
Reinforcement

Concrete is weak in tension

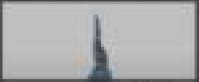


What if we add fibers while making the concrete?

https://www.youtube.com/watch?v=[illegible]



What is going on?



Fibers **do not** stop the cracks from forming.

If you can't see the cracks are they really there?

small cracks = long life

Toughness

Microfibers –

Fresh concrete

1 – 6 h

Hot, windy, sunny

Plastic shrinkage cracking

Macrofibers –

Hardened concrete

days to years

Usually > ½" (12.5 mm)

Stiff material

Summary -

Fibers are often the only reinforcement choice for thin members or members that are too complicated for rebar.

Fibers are a great tool to reduce cracking and increase toughness.

Not all fibers are the same!

Aramid Fibers

Meaning of Aramids

Ar – amid

Origin: Aromatic Amides

Meaning: Amide linkages attached with two aromatic rings also called aromatic polyamides.

A synthetic polymer of a type made by the linkage of an amino group of one molecule and a carboxylic acid group of another, including many synthetic fibres such as nylon.

1.ARAMID FIBER :

CHARACTERISTICS

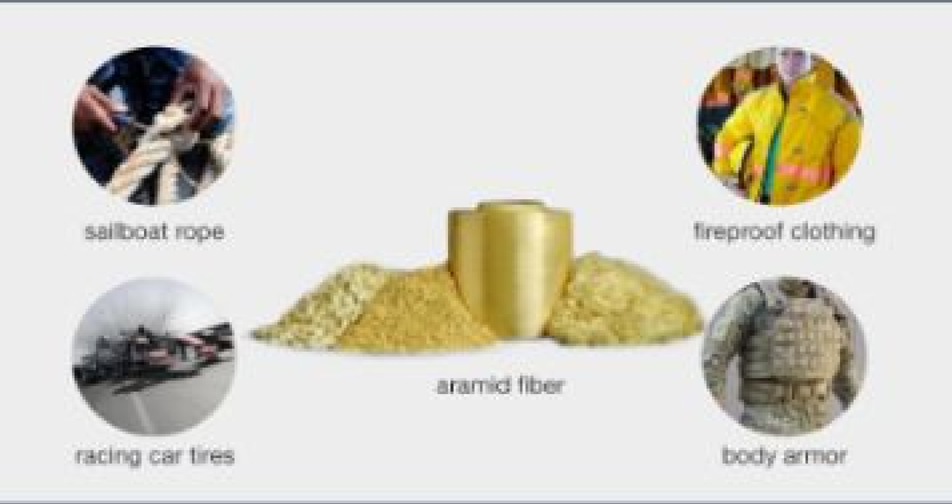
- **Fiber structure** : A series of synthetic polymer(substance which has a molecular structure built up chiefly or completely from a large number of similar units bonded together) in which repeating units containing large phenyl rings are linked together by amide groups..
- Fiber properties: They are characterized by **medium to ultra-high strength, medium to low elongation and moderately high to ultra-high modulus with the densities** ranging from **1.38g/cm3 to 1.47g/cm3.**

ARAMID FIBER CHARACTERISTICS :

- **Chemical properties:** All aramids contain amide links that are hydrophilic.(**having a tendency to mix with, dissolve in, or be wetted by water.**) However, not all aramid products absorb moisture the same.
- Also, the aromatic nature of para-aramid is responsible for oxidative reactions when exposed to UV light, that leads to a change in color and loss of some strength.
- **Thermal properties:** Aramid fibers do not melt in the conventional sense but decompose simultaneously.
- Aramids show high crystallinity which results in negligible shrinkage at high temperature.
- **Mechanical properties:** High strength is a result of its aromatic and amide group and high crystallinity.
- Aramid retains strength and modulus at temperatures as high as 300 degrees Celcius. **It behaves elastically under tension. When it comes to severe bending, it shows non-linear plastic deformation.**

aramid general characteristics are:

- High strength
- Resistance to absorption
- Resistance to organic solvent, good chemical resistance
- No conductivity
- No melting point
- Low flammability
- Excellent heat, and cut resistance
- Sensitive to acids and ultraviolet radiation


sailboat rope
fireproof clothing
aramid fiber
racing car tires
body armor

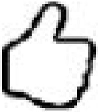
APPLICATIONS

- Aramid fiber applications are divided into two categories:
- A) Reinforcement in composites like sport goods, aircraft, military vehicles and many other.
- B) Fabrics in clothing such as fire protection clothes or bullet proof vests.
- Although every application meets its own requirements, almost all of them share aramid's major characteristics:
- high strength, high modulus, high toughness, thermal dimensionality stability, low creep and light weight

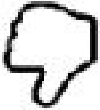
ARAMID IN COMPOSITES

- In a world where **lightweight and durable composites are increasingly replacing conventional materials**, aramid and para-aramid fibers play an important role.
- They are essential for reinforcing composites where weight reduction and excellent damage tolerance are required.
- Many **different kinds of composite goods are reinforced with aramid** because of the strength, stiffness and dimensional stability of laminates that contain it.

- Aramid main advantages are high strength and low weight.
- Like graphite, it has a slightly negative axial coefficient of thermal expansion, which means aramid laminates can be made thermally stable in dimensions.
- Unlike graphite, it is very resistant to impact and abrasion damage.
- **It can be made waterproof when combined with other materials like epoxy.**
- It can be used as a composite with rubber retaining its flexibility.
- High tensile modulus and low breakage elongation.



LIMITATIONS:



- On the other side, aramid has a few disadvantages.
- **The fibers absorb moisture, so aramid composites are more sensitive to the environment than glass or graphite composites.**
- Compressive properties are relatively poor too.
- Also, aramid fibers are difficult to cut and to grind without special equipment (e.g. special scissors for cutting, special drill bits). Finally, they suffer some corrosion and are degraded by UV light. For this reason they must be properly coated.

- Types of Advanced Concrete :

Reinforcement

Aramid Fibre

Bio Steel

High Performance Concrete

Translucent Concrete

Autoclaved Aerated concrete

Bendable Concrete

Light Transmitting Concrete

Pervious Concrete

Floating Concrete

Ecocement

Carbon Fibre

Fibre Glass

Reinforcement

2.BIOSTEEL

- BioSteel is a trademark name for a high strength based fiber material made of the recombinant spider silk-like protein extracted from the milk of transgenic goats, made by Nexia Biotechnologies.
- This and other biopolymers are being researched to provide lightweight, strong, and versatile materials.
- Biosteel is eco-friendly both in terms of its composition and it production process.
- Aqueous production process is non polluting and environmentally friendly in contrast to t manufacturing of other synthetic fibre.

PROPERTIES OF SPIDER SILK

- Spider silk incredibly tough and its stronger by weight than steel (five times stronger steel of the same diameter).
- Spider silk is a strong and the toughest man made polymer.
- Finer than the human hair.
- Spider silk – very elastic and capture silk (sticky silk for catching prey) remains unbroken after being streched 2 to 4 times its original length. Water proof than silkworm silk.

https://www.youtube.com/watch?v=[illegible]

APPLICATION OF BIOSTEEL

- The first uses of BIOSTEEL in medical field is microsurgery using super-thing biodegradable sutures.
- For the production of artificial tendons or ligaments,
- For haemostatic dressings (eye surgeries).
- Artificial ligaments
- Bulletproof vests
- Improved car airbags
- More reliable parachutes

- Types of Advanced Concrete :

Reinforcement

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Floating Concrete

Ecocement

Carbon Fibre

Fibre Glass

Reinforcement




3.FIBERGLASS:

- A fiberglass is a form **of fiber-reinforced plastic** where **glass fiber** is the reinforced plastic. This is the reason perhaps why fiberglass is also known as glass reinforced plastic or glass fiber reinforced plastic.
- The glass fiber is usually flattened into a sheet, randomly arranged or woven into a fabric. According to the use of the fiberglass, the glass fibers can be made of different types of glass.
- **Fiberglass is lightweight, strong and less brittle. The best part of fiberglass is its ability to get molded into various complex shapes.** This pretty much explains why fiberglass is widely used in bathtubs, boats, aircraft, roofing, and other applications.

Properties of fiberglass :

- **Mechanical strength**: Fiberglass has a specific resistance greater than steel. So, it is used to make high-performance
- **Electrical characteristics**: Fiberglass is a good electrical insulator even at low thickness.
- **Incombustibility**: Since fiberglass is a mineral material, it is naturally incombustible. It does not propagate or support a flame. It does not emit smoke or toxic products when exposed to heat.
- **Dimensional stability**: Fiberglass is not sensitive to variations in temperature and hygrometry. It has a low coefficient of linear expansion.
- **Compatibility with organic matrices**: Fiberglass can have varying sizes and has the ability to combine with many synthetic resins and certain mineral matrices like cement.
- **Non-rotting**: Fiberglass does not rot and remains unaffected by the action of rodents and insects.
- **Thermal conductivity**: Fiberglass has low thermal conductivity making it highly useful in the building industry.
- **Dielectric permeability**: This property of fiberglass makes it suitable for electromagnetic windows.

Forms of Fibre glass :

Fiberglass comes in various forms to suite various applications, the major ones being:

- **Fiberglass Tape:** Fiberglass tapes are made up of glass fiber yarns and are known for their thermal insulation properties. This form of fiberglass finds wide applications in wrapping vessels, hot pipelines, and the likes.
- **Fiberglass Cloth:** Fiberglass cloth is smooth and is available in various variants like glass fiber yarns and glass filament yarns. It is widely used as **heat shields, in fire curtains and others.**
- **Fiberglass Rope:** Ropes are braided (edged) from glass fiber yarns and are used for packing purposes.

YARN

APPLICATION OF FIBRE GLASS

- **Materials with high-temperature insulation** provide an effective thermal barrier for **industrial gaskets.** Since fiberglass is durable, safe and offers high thermal insulation, fiberglass is one of the widely preferred materials in **industrial gaskets**. They not only provide a better insulation but **also help in protecting the machinery, conserving the energy and ensure the safety of the professional workforce. This is the reason perhaps why fiberglass is widely used in industries given below:**

- **Beverage Industry**: Fiberglass grating is used in many areas like bottlinglines and in brew houses.

- **Car washes**: Recently, fiberglass grating is greatly used for rust resistance and to give a contrast color to areas that previously looked forbidden. It brightens the inside of the carwash tunnel making the car look cleaner thanit was.

- **Chemical Industry**: In this industry, the **fiberglass grating is used for anti-slip safety feature of the embedded grit surface** and **the chemically resistant feature of different resin compounds.** The chemicals being used are matched with the resins.

- **Cooling towers:** Since cooling towers are always wet, they have to be protected from rust, corrosion, and other safety issues. Due to the excellent properties of fiberglass, it is used in these towers as screening to keep people and animals away from the danger zones.

- **Docks and marinas:** The docks get corroded, rusted and damaged by the salty sea water. So, fiberglass is used here for protection.

- **Food processing:** In the chicken and beef processing plants, fiberglass grating(HARSH) is used for slip resistance and for holding up to blood which is corrosive. Most of the areas of food processing also use fiberglass as other grating materials are not suitable.

- **Fountains and aquariums:** All sizes of fountains and aquariums use fiberglass to support rocks to help in circulation and filtering from under the rocks. In large public fountains, fiberglass grating is used to protect spray headers and lights from getting damaged. This also keeps people from drowning in the fountains.

- **Manufacturing** : The embedded grit surface of fiberglass grating ensures slip resistance in the areas that are wet or in places where hydraulic fluids or oils are present.

- **Metals and mining :** Fiberglass grating is used in **electronic refining areas prone to chemical corrosion.** Other grating materials cannot be used here.

- **Power generation :** Many areas of the power generation industry like tank farms, scrubbers, and others use **fiberglass. The reason for this is the non-conductive property of fiberglass.**

- **Plating plants :** This application uses fiberglass grating due to the anti-slip property of the surface.

- **Pulp and paper industry:** The property of fiberglass which makes it chemical corrosion resistant is useful in pulp and bleach mills. Recently, fiberglass is used in many areas due to its corrosion resistance and anti-slip properties.

- **Automotive industry:** Fiberglass is extensively used in automobile industry. Almost every car has fiberglass components and body kits.

- **Aerospace & Defense:** Fiberglass is used to manufacture parts for both military and civilian aerospace industry including test equipment, ducting, enclosures, and others.

4.CARBON FIBRE:

- Carbon fibers or carbon fibres (alternatively CF, graphite fiber or graphite fibre) are fibers about 5–10 micrometres in diameter and composed mostly of carbon atoms.
- Carbon fibers have several advantages including **high stiffness, high tensile strength, low weight, high chemical resistance, high temperature tolerance and low thermal expansion**.
- These properties have made carbon fiber very popular in **aerospace, civil engineering, military, and motorsports, along with other competition sports**. However, they are **relatively expensive when compared with similar fibers, such as** glass fibers **or plastic fibers.**

- Several thousand carbon fibers are bundled together to form a tow(pull), which may be used by itself or woven into a fabric.
- To produce a carbon fiber, the carbon atoms are bonded together in crystals that are more or less aligned parallel to the long axis of the fiber as the crystal alignment gives the fiber high strength-to-volume ratio (in other words, it is strong for its size).
- Carbon fibers are usually combined with other materials to form a composite.

APPLICATION OF CARBONFIBRE :

- **The strongest demand for carbon fiber come from aircraft and aerospace, wind energy, as well as the automotive industry with optimized resin systems.**

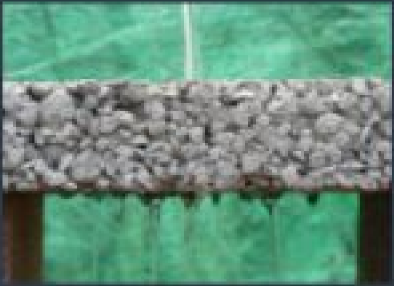
  Carbon fiber can have higher cost than other materials which has been one of the limiting factors of adoption. In a comparison between steel and carbon fiber materials for automotive materials, carbon fiber may be 10- 12x more expensive.

- Composite materials-Carbon fiber is most notably used to reinforce composite materials, particularly the class of materials known as carbon fiber or graphite reinforced polymers.
- Carbon fiber can be used as an additive to asphalt to make electrically-conductive asphalt concrete
- Flexible heating -carbon fiber Known for their conductivity.

Brainstorming Session

1.What is that concrete sometimes referred to as "**no-fines concrete**"??

Pervious Concrete



2. What is the material Developed in Sweden in the 1920s in response to increasing demands on timber supplies??

AAC




3. What is the concrete which reduces the beam depth??

4. What is the difference in terms of the components in a traditional concrete & that aerated concrete ?

5. What is the concrete which has no coarse aggregate ??

Light Transmitting Concrete

6. What is the material we saw today serve as a water proof material when coated with epoxy??

Light Transmitting Concrete

7. A Fiberglass is a form of .... Plastic , & the fibers are ....??

Fibre Reinforced Plastic & the fibers are glass

8. Carbon Fibre is an alternative for ??

Graphite fibre

9. What is the material known for corrosion resistance is used in Industries ??

Fibre Glass


Information

UNIT -3

Types, terminology and classification of composite materials based on **particle reinforced, fiber reinforced**, structuraland composite benefit in building construction.
Composite materials manufacturing process.

Use of composite materials namely Polymer Matrix Composites (PMCs) and Fibre- Reinforced Polymers (FRPs) along with cement, steel, aluminium ,wood, glass, etc., for thermal insulation, fire protection, coating, painting and structural monitoring, etc.

COMPOSITE MATERIAL ??

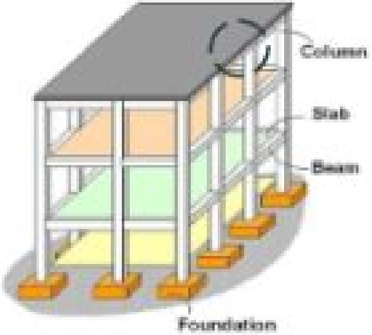
- A composite material is a combination of two materials with different physical and chemical properties. **Two or more chemically distant materials which when combined have improved properties over individual materials.**
- When they are combined they create a material which is specialised to do a certain job, for instance to become stronger, lighter or resistant to electricity. They can also improve strength and stiffness.
- The reason for their use over traditional materials is because they improve the **properties of their base materials and are applicable in many situations.**

SFMOMA expansion' by snohetta in san francisco, california, USA

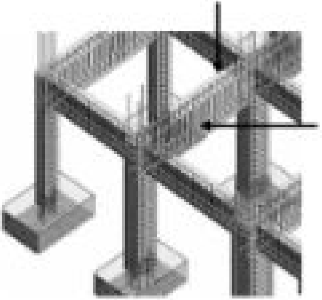
The iconic eastern facade of the Snøhetta-designed expansion, inspired in part by the **waters and fog** of the San Francisco Bay , Comprised of more than 700 uniquely shaped and locally fabricated FRP **(fiberglass reinforced polymer)** panels. Throughout the day, **the movement of light and shadow naturally animates the rippled surface.** Silicate crystals from Monterey County embedded in the surface catch and reflect the changing light.

Advantage of a composite: The composite retain their identities in the composite that is they donot dissolve in or merge completely into each other, although they act in concert.

Instance 1:Reinforced Concrete



Concrete is good in compression and weak in tension



So steel is provided, which is good in tension

Finally a stable structure is achieved based on the combined properties.

- Concrete is a well-known composite material that has been used for a long time in the construction of buildings and bridges.
- **Concrete is made from small stones and gravel called aggregate, sharp sand and cement. The small stone and gravel (aggregate) is the reinforcement** and the cement is the matrix that binds it together.
- Concrete has good strength under compression but it is weak in tension. It can be made stronger under tension by adding **metal rods, wires, mesh or cables to the composite**. The concrete is cast around the rods. This is called **reinforced concrete**.
- Lintels are the beams used above doors, windows and fireplaces. They support the weight of all the bricks bearing down on the window frames, doorframes or fireplace openings. When houses were first built the lintels were made from solid, heavy beams of **timber**. Most lintels these days are made from **reinforced concrete**.

* **Mud-brick**

(Straw mixed with mud)

* **Chipboard**

(Small pieces of wood mixed with glue)

- **Humans have been using composite materials for a long time in order to build our dwellings.**
- Some of the earliest forms of building were built of **mud bricks.**
- Mud bricks work well **when they are being compressed (compression forces) but a cake of mud is easily broken if it is bent (bending forces).**
- This is because the act of bending places a tension force on one edge.
- At the same time as the mud block buildings were being built other people were making straw dwellings.
- Straw has a great deal of tensile strength (resistance to pulling forces) but it is very weak when crumpled. (wrinkled)
- These early builders realised was that if straw, which has a good tensile strength was embedded in a block of mud, which has good compressive strength and left to dry the resulting brick would resist both tearing and squeezing.
- **These composite bricks made excellent building materials.**

- Many composites are made up of just two materials.
- One material called the matrix or binder surrounds and binds together a cluster of fibres of a much stronger material called the reinforcement.
- In the case of mud bricks **the mud became the matrix** and **the straw became the reinforcement.**

Instance 3 :Fibreglass

- Fibreglass was developed in the late 1940s. It was the **first modern composite and is still the most common**. It makes up about **65 %of all the composite materials produced today. GRP or glass fibre reinforced plastic consists** of two distinct materials, a **fibres of glass (ceramic), which is the reinforcement** and **a polymer resin called polyester, which serves as the matrix.**

- The polyester resin polymer alone is brittle and has a low strength but when fibres of glass are embedded in the polymer it becomes strong, tough, resilient and flexible.

- It becomes an ideal material to make boat hulls, swimming pool linings, car bodies, roofing and furniture. The other advantage of GRP is that it is very light. It is said to have a very good strength to weight ratio. A resilient material is one that returns to its original shape after bending, twisting, stretching, compression.

- A tough material is one that has the ability to withstand sudden blows or shocks without breaking. This material can also be bent without cracking. The image below is of a GRP flight simulator.

WHY SHOULD WE USE COMPOSITES?

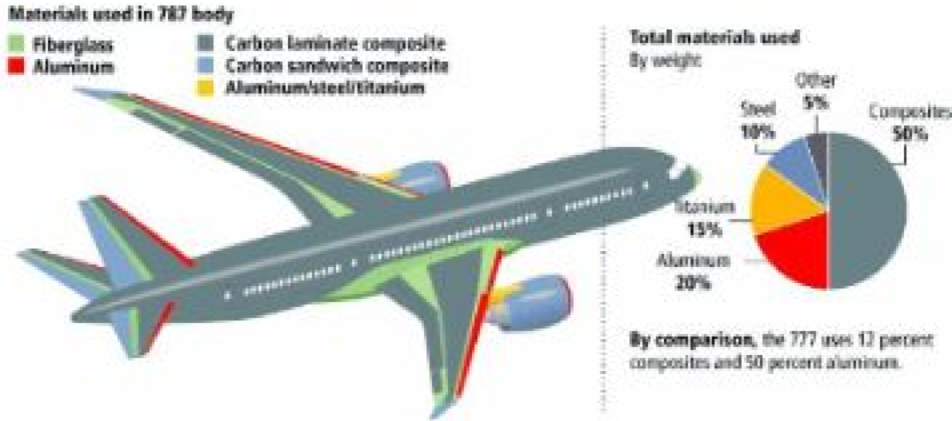
- Weight saving is one of the main reasons for using composite materials rather than conventional materials for components.

- While composites are lighter they can also be stronger than other materials, for **example, reinforced carbon-fibre can be up to five times stronger than 1020 grade steel and only one fifth of the weight, making it perfect for structural purposes.**

- Another advantage of using a composite over a conventional type of material is the thermal and chemical resistance as well as the electrical insulation properties. Unlike conventional materials, composites can have multiple properties not often found in a single material.

- Fibre reinforced composites, such as fibre reinforced plastic (FRP composites), are finding increasing use in the design and manufacture of final products for commercialisation.

EXAMPLE OF COMPOSITE MATERIAL :



- Composites have good tensile strength and resistance to compression, making them suitable for use in aircraft part manufacture.
- Fuel consumption depends on several variables, including: dry aircraft weight, payload weight, age of aircraft, quality of fuel, air speed, weather, among other things. The weight of aircraft components made of composite materials are reduced by approximately 20%, such as in the case of the 787 Dreamliner.

- A carbon- and glass-fibre-reinforced plastic (CFRP and GFRP respectively) that consist of carbon and glass fibres, both of which are stiff and strong (for their density)
- but brittle,
- in a polymer matrix, which is tough but neither particularly stiff nor strong.
- by combining materials with complementary properties in this way , a composite material with most or all of the benefits (high strength, stiffness, toughness and low density) is obtained with few or none of the weaknesses of the individual component materials.

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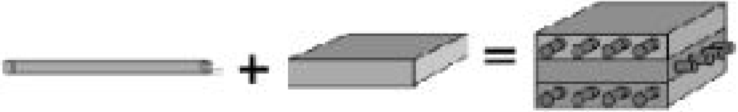
COMPONENTS OF COMPOSITE MATERIAL :



Fiber/Filament Reinforcement	Matrix	Composite
• High strength • High stiffness • Low density	• Good shear properties • Low density	• High strength • High stiffness • Good shear properties • Low density

- Two materials in which one of the materials,
- **reinforcing phase**- in the form of fibers, sheets, or particles.
- And is embedded in the other materials called the **matrix phase**.

PHASE OF A COMPOSITE MATERIAL :

A composite material consists of two phases:

Primary:

- Forms the matrix within which the secondary phase is imbedded
- Any of three basic material types: polymers, metals, or ceramics

Secondary:

- Referred to as the imbedded phase or called the reinforcing agent
- Serves to strengthen the composite (fibers, particles, etc.)
- Can be one of the three basic materials or an element such as **carbon or boron**

-- Matrix - is continuous
-- Dispersed - is discontinuous and
surrounded by matrix

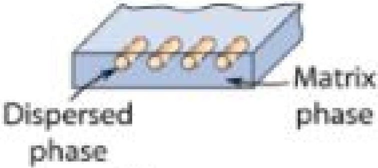


Fig.1

What are the functions of a matrix?

1. Holds the fibres together

2. Protects the fibres from environment

3. Protects the fibres from abrasion (with each other)

4. Helps to maintain the distribution of fibres

5. Distributes the loads evenly between fibres

6. Enhances some of the properties of the resulting material and structural component component (that fibre alone is not able to impart) impart). These properties properties are such as: transverse strength of a lamina impact resistance

7. Provides better finish to final product

Essentials of matrix phase

- It should be ductile
- Bonding strenth should be high
- Corrosion resistant

What are the functions of a reinforcement?

1. Contribute desired properties
2. Load carrying
3. Transfer the strength to matrix

REASON TO USE COMPOSITE MATERIAL

- Higher specific strength than metals, non-metals and even alloys. Lower specific gravity in general.
- Improved stiffness of material.
- Composite maintain their weight even at high temperatures.
- Toughness is improved.
- Fabrication or production is cheaper.
- Creep and fatigue strength is better.
- Controlled Electrical conductivity is possible.
- Corrosion and oxidation resistance.

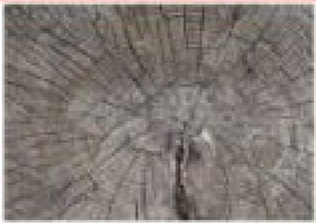
EXAMPLES OF COMPOSITE USES

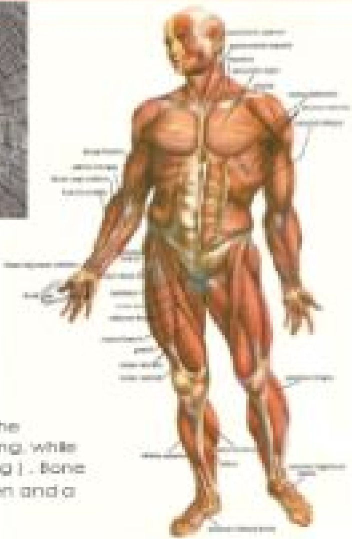
- Electrical equipment
- Aerospace structures
- Infrastructure
- Pipes and tanks
- Homes can be framed using plastic laminated beams

Composite: Examples from Day-to-Day Life

Examples:

1. Straw-bricks
2. Concrete
3. Wood
   (cellulose + lignin)
4. Human body
   (muscles + bones)
5. Tyres
6. Plywood
7. Sports good ……………………………





Wood and bone are **examples** of natural **composites**. ... The cellulose fibers give wood its ability to bend without breaking, while the lignin makes wood stiff (quality of being severe or strong) . Bone is a combination of a soft form of protein known as collagen and a strong but brittle mineral called apatite.

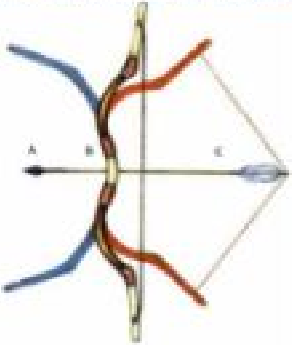
Composite: Formal Definition

History: **Oldest application/existence of composite material?**

4000 B.C. – laminated writing material from the papyrus plant

1300 B.C. – Egyptians and Mesopotamian used straw bricks

1200 A.D. - Mongols invented the first composite bow



First Bow of wood, bamboo, bone, cattle tendons, horn and silk bonded with pine resin.

Composite: Formal Definition and History

Composite Bow – dates back to 3000 BC (Angara Dating)

Materials Used:

Wood, Horn, Sinew (Tendon), Leather, Bamboo and Antler (Deer horn)

Horn and Antler: naturally flexible and resilient

Sinews: back tendons or hamstrings of cows and deer

Glue: From bladder of fish

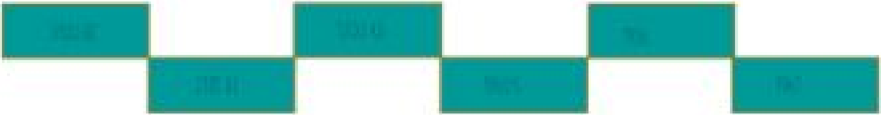
Strings: Sinew, Horse hair, Silk

Overall processing time was almost a year !

Source: http://medieval2.heavengames.com

BRIEF HISTORY

- In **3400 B.C** the first composites were engineered by the Mesopotamians in Iraq. The ancient society glued wood strips on top of each other at different angles to create plywood.
- Following this, in around **2181 B.C** the Egyptians started to make death masks out of linen or papyrus soaked in plaster. Later on, both of these societies started to reinforce their materials with straw to strengthen mud bricks, pottery and boats.
- In **1200 A.D**. the Mongols began to engineer composite bows which were incredibly effective at the time. These were made out of wood, bamboo, bone, cattle tendons, horn and silk bonded with pine resin.
- Following the industrial revolution, synthetic resins started to take a solid form by using polymerisation. In the **1900s** this new-found knowledge about chemicals led to the creation of v ariousplastics such as polyester, phenolic and vinyl.
- Synthetics then started to be developed. Bakelite was created by the chemist Leo Baekeland. The fact that it did not conduct electricity and was heat resistant meant it could be widely used across many industries.
- The **1930s** was an incredibly important time for the advancement of composites. Glass fibre was introduced by Owens Corning who also started the first fibre reinforced polymer (FRP) industry.



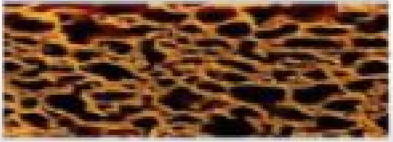
- The resins engineered during this era are still used to this day and, in **1936**, unsaturated polyester resins were patented. Two years later, higher performance resin systems became accessible.
- The first carbon fibre was patented in **1961** and then became commercially available. Then, in the **mid-1990s**, composites were starting to become increasingly common in manufacturing and construction due to their relatively cheap cost compared to materials that had been used previously.
- The composites on a Boeing 787 Dreamliner in the **mid- 2000s** substantiated their use for high strength applications.

Composite

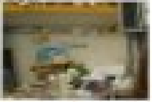
- Combination of two or more individual materials, can be natural or synthetic

- Design goal: obtain a more desirable combination of properties (principle of combined action)
  - e.g., low density and high strength

The Bone in our body is a composite. It is made from a hard and brittle material called *Hydroxyapatite* (which is mainly calcium phosphate) and a soft and flexible material called collagen (which is a protein).



Img & Txt credit: Oan Sahito

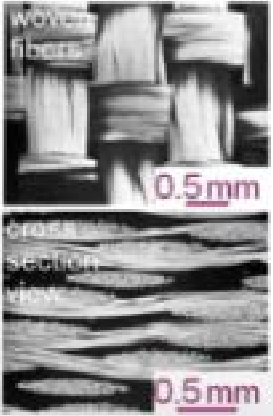


Terminology/Classification

- Matrix phase:
  - -- Purposes are to:
    - transfer stress to dispersed phase
    - protect dispersed phase from environment
  - -- Types: MMC, CMC, PMC

metal matrix composite ceramic polymer

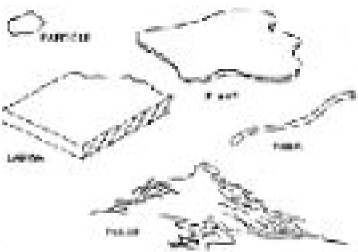
- Dispersed phase:
  - -- Purpose:
    - MMC: increase σ_y, TS, creep resist.
    - CMC: increase K_{Ic}
    - PMC: increase E, σ_y, TS, creep resist.
  - -- Types: particle, fiber, structural

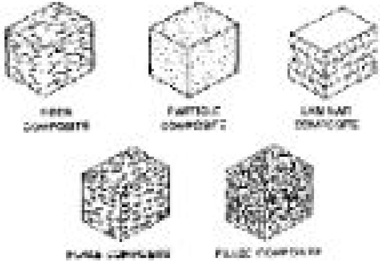


Reprinted with permission from D. Hull and T.W. Clyne, An Introduction to Composite Materials, 2nd ed., Cambridge ... New York, 1996, Fig...

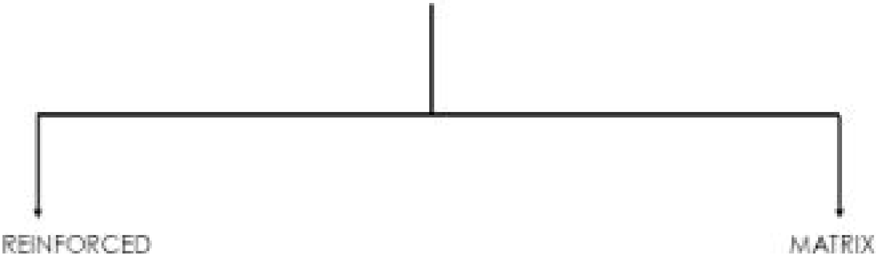
TYPES OF COMPOSITE MATERIALS :

- There are five basic types of composite materials: Fiber, flake, laminar or layered and filled composites.

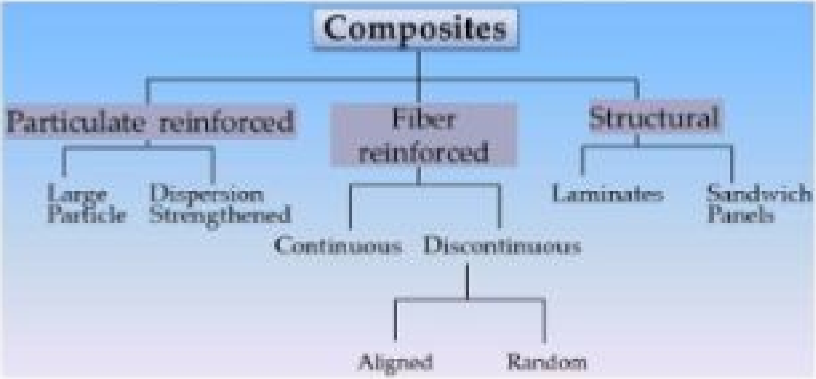




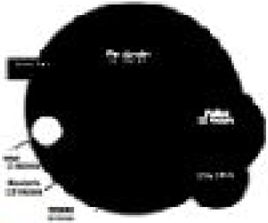
CLASSIFICATION OF COMPOSITE MATERIALS:



CLASSIFICATION BASED ON REINFORCED :



The reinforcing material and the matrix material can be metal, ceramic, or polymer. Composites are used because overall properties of the composites are superior to those of the individual components.



PARTICULATES

- Equal sized, spherical reinforcement material
- Imparts least anisotropic property to composite

FIBERS

- Long relative to particulates

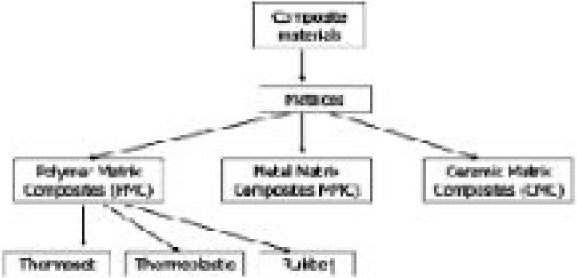
LAMINATES

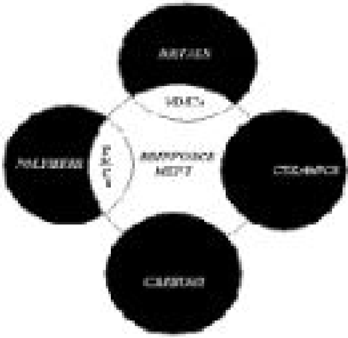
- Layer-by-layer Structure

- Honey Comb Structure (HCS)

- Honey comb cells are filled with flexible material.
- Higher strength, Stiffness along the columnar side (Upside) of the HCS.
- Lower strength when pressed from sides.

CLASSIFICATION BASED ON MATRIX :





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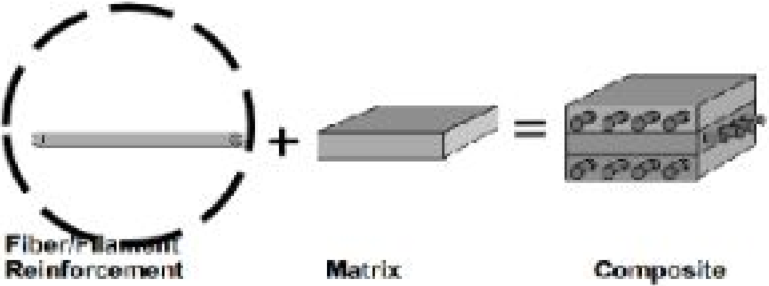
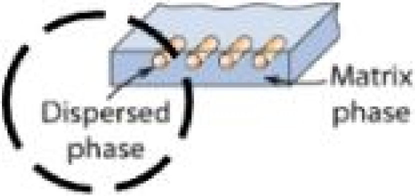
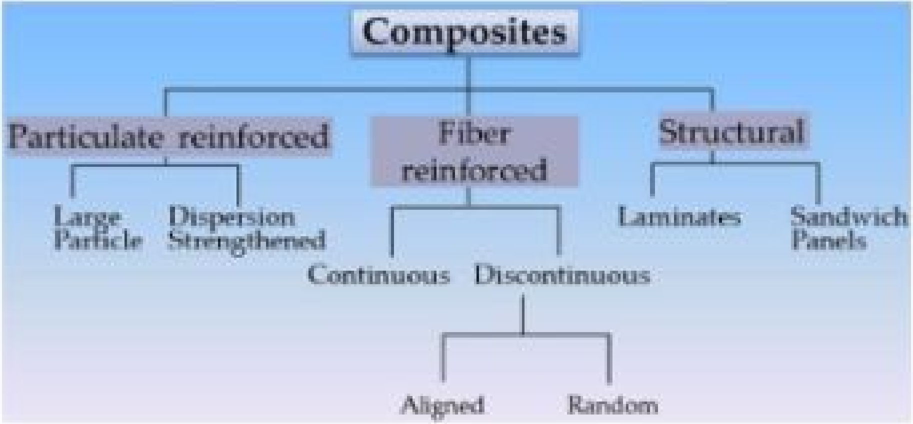




CLASSIFICATION OF COMPOSITES(REINFORCED):

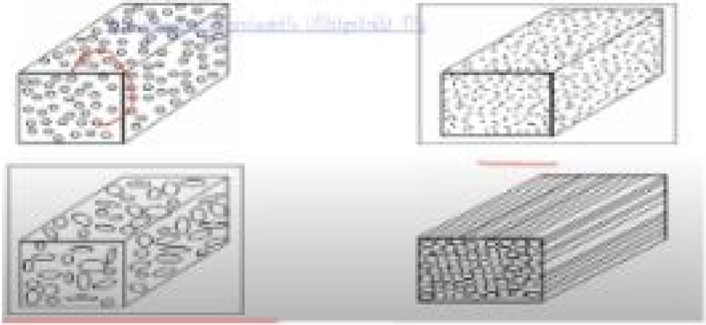
- Particle-reinforced composites
- Fiber-reinforced composites
- Structural composites



Particle-reinforced composites

- Used in particle reinforcing
- ceramics, glasses (small mineral particles)
- metal particles (aluminium, and amorphous materials) polymers and carbon black

  Example:
- CONCRETE where the aggregetes (sand and gravel) are the particles and cement is the matrix. Particle reinforced composites support higher tensile, compressive and shear stresses.



Fiber-reinforced composites:

Fiber-reinforced Composites are made of:

- metals, ceramics, glasses, or polymers that have been turned into graphite and known as carbon fibers.
- Fibers increase the modulus (measure of its stiffness) of the matrix material.

Uses of Fiber-reinforced composites

- **sports equipment, such as a time-trial racing bicycle frame which consists of carbon fibers in a thermoset polymer matrix.**
- **Body parts of race cars and some automobiles are composites made of glass fibers (or fiberglass) in a thermoset matrix.**

Structural composites

A structural composite consists of both homogeneous and composite material. There properties depend on, the characteristic properties of the constituent materials as well as the geometric design.

Structural composite are of two types:-

1.Laminar Compost

2.Sandwich Panel

Advantages

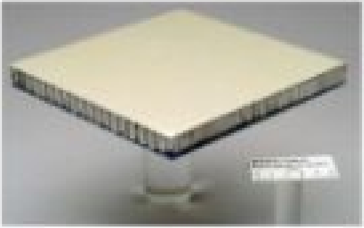
- Weight reduction (approximately 20-50%)
- Corrosion resistance
- Fatigue resistance
- Tailorable mechanical properties
- Sales through offset
- Lower assembly costs (fewer fasteners, etc.)

Disadvantages

- Some higher recurring costs
- Higher nonrecurring costs
- Higher material costs
- Nonvisible impact damage
- Repairs are different than those to metal structure
- Isolation needed to prevent adjacent aluminum part galvanic corrosion

STRUCTURAL MATRIX :

- Structural Composites: Sandwich Panels: Consist of two strong outer sheets which are called face sheets and may be made of aluminum alloys, fiber reinforced plastics, titanium alloys, steel.
- Face sheets carry most of the loading and stresses.
- Core may be a honeycomb structure which has less density than the face sheets and resists perpendicular stresses and provides shear rigidity.
- Sandwich panels can be used in variety of applications which include roofs, floors, walls of buildings and in aircraft, for wings, fuselage and tailplane skins.



BENEFITS OF COMPOSITE CONSTRUCTION

- The benefits of composite construction include speed of construction, performance and value.
- Steel framing for a structure can be erected quickly and the pre- fabricated steel floor decks can be put in place immediately. When cured, the concrete provides additional stiffness to the structure.
- Additionally, the concrete encasement protects the steel from buckling, corrosion and fire. Service integration within the channels on the composite decks is another advantage to composite construction.
- Building quality standards can be adhered to easily by the use of pre-fabricated decks.
- Excessive deflections can be controlled by cambering the beams or by shoring the metal decks to limit deflection when concrete is poured.

DIFFERENT TYPES

Some common composite materials include:

- **Ceramic matrix composite:** Ceramic spread out in a ceramic matrix. These are better than normal ceramics as they are thermal shock and fracture resistant.
- **Metal matrix composite**: A metal spread throughout a matrix
- **Reinforced concrete**: Concrete strengthened by a material with high tensile strength such as steel reinforcing bars.
- **Glass fibre reinforced concrete**: Concrete which is poured into a glass fibre structure with high zirconia content.
- **Translucent concrete**: Concrete which encases optic fibres.
- **Engineered wood**: Manufactured wood combined with other cheap materials. One example would be particle board. A speciality material like veneer can also be found in this composite.
- **Plywood**: Engineered wood by gluing many thin layers of wood together at different angles.
- **Engineered bamboo**: Strips of **bamboo fibre glued together to make a board**. This is a useful composite due to the fact it has higher compressive, tensile and flexural strength than wood

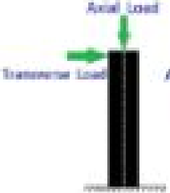
- **Parquetry**: A square of many wood pieces put together often out of hardwood. It is sold as a decorative piece.
- **Wood-plastic composite**: Either wood fibre or flour cast in plastic.
- **Cement-bonded wood fibre**: Mineralised wood pieces cast in cement. This composite has insulating and acoustic properties.
- **Fibreglass**: Glass fibre combined with a plastic which is relatively inexpensive and flexible.
- **Carbon fibre reinforced polymer**: Carbon fibre set in plastic which has a high strength-to-weight ratio.
- **Sandwich panel**: A variety of composites that are layered on top of each other.
- **Composite honeycomb**: A selection of composites in many hexagons to form a honeycomb shape.
- **Papier-mache**: Paper bound with an adhesive. These are found in crafts.
- **Plastic coated paper**: Paper coated with plastic to improve durability. An example of where this is used is in playing cards.
- **Syntactic foams**: Light materials created by filling metals, ceramics or plastics with microballoons. These ballons are made using either glass, carbon or plastic

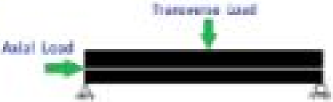
APPLICATIONS OF COMPOSITE MATERIAL

- In automobile industries (e.g. Steel &Aluminium body)
- Marine applications like shafts, hulls, spars (forracing boats)
- Aeronautical application like components of rockets, aircrafts
- (business and military),missiles etc.
- Communication antennae, electronic circuit boards (e.g. PCB,breadboard)
- Safety equipment like ballistic protection and Air bags of cars.

FAILURE OF COMPOSITE MATERIAL

- Failure under longitudinal compressive loading
- Failure under longitudinal tensile loading





MANUFACTURING PROCESSES :

In function of composite constructions, those can be divided in two categories

- Laminates, which have layers bonded together.
- Sandwiches, which are multiple-layer structural materials containing a low- density core between thin faces (skins) of composite materials.
- [illegible]

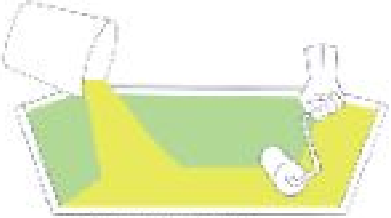
Composites fabrication have many processes, some of the most important processes are
- Hand and automated tape lay-up,
- Resin injection,
- Compression molding,
- Pultrusion,
- Filamentwinding.

Other classification of composites process can be after the process volume, which due to of two categories: high and low volume.

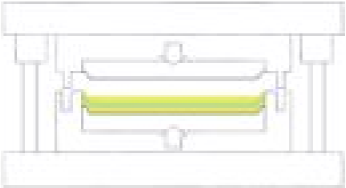
- Low-volume processes are manual and low-pressure spray lay-up in low-cost molds with a high working cost.
- High-volume processes, such as lamination, filament-winding, pultrusion and resin transfer molding, have an initial high cost for tooling and installation, which are compensated by low-intensity of working.

- In addition, lamination processes can be found in both of them, lamination as a hand lay-up process, or as the automated using sheet-molding compounds. Lamination, filament winding, pultrution and resin transfer molding are relevance in production of continuous fiber composites with closely controlled properties, being used for Obtained or comparative flat parts.

- A potential and high-speed process in fabrication of tubs and other cylindrical parts represents the filament -winding process, in which time the pultrusion process is applied for fabrication of parts with constant cross-sectional shapes, and resin transfer molding shares some similarities with injection molding.



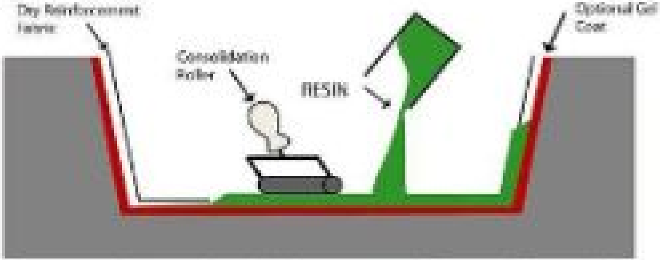
OPEN MOULDING



CLOSED MOULDING

CAST POLYMER MOULDING

1.Handlay



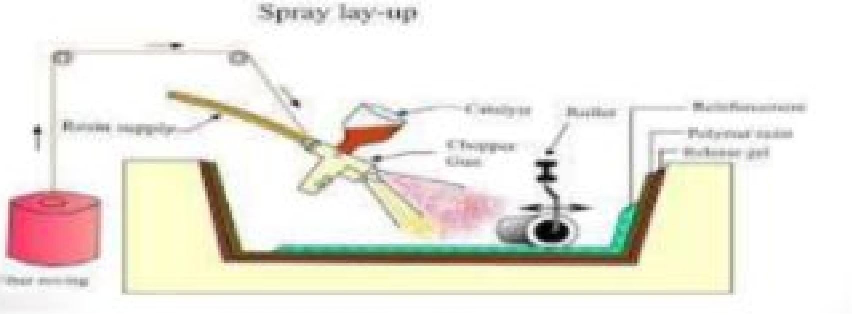
- Composites are engineered materials composed of a matrix material (e.g. polyester or epoxy resins) and a reinforcing material (e.g. glass mat or woven fabric). The process of making a composite is termed Composite Layup, which is derived from the original method of making these materials.

- In hand layup (see Figure 1) the resins are impregnated by hand into the reinforcing fibers. Rollers and brushes are used to incorporate the resin into the fibers and to remove air from the composite.

- Hand layup is a low volume, labor intensive method suited for boat hulls or other large items. The fibers are positioned manually in the open mold, and resin is poured, brushed, or sprayed over the mat. Room temperature curing resins are commonly used. For a high quality part surface, a pigmented gel coat is first applied to the mold surface.

USE : boats, tanks, bathware, housings, RV/truck/auto components, architectural prod

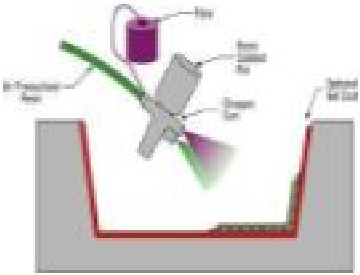
2.Sprayup-Process



SPRAY UP PROCESSES:

- In spray up process liquid resin matrix and chopped reinforcing fibers are sprayed on to the mold surface.
- The fibers are chopped in **to fibers of 25-50mm length** and then sprayed by an air jet at a predetermined ratio between **the reinforcing and matrix phase.**
- The spray up method permits rapid formation of uniform composite coating, however mechanical properties of the material are moderate since the method is unable to use continuous reinforcing fibers.

Sprayup-Process



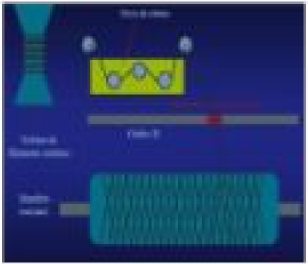
A chopped laminate has good conformability **(the ability of the substance to mould to a shape)** and is sometimes faster than hand lay-up in **molding complex shapes.** In the spray-up process the operator controls **thickness and consistency**, therefore the process is more operator dependent than hand lay-up. **Although production volume per mold is low, it is feasible to produce substantial production quantities using multiple molds.**

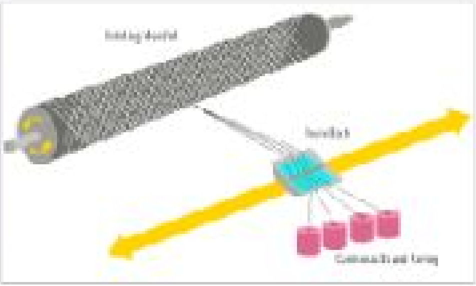
- **As with hand lay-up, gel coat is first applied to the mold prior to spray-up of the substrate laminate.** Continuous strand glass roving(moving) and catalyzed resin are fed through a chopper gun, which deposits the resin-saturated "chop" on the mold.

- The laminate is then rolled to thoroughly saturate the glass strands and compact the chop. Additional layers of chop laminate are added as required for thickness.

- Roll stock reinforcements, such as woven roving or knitted fabrics, can be used in conjunction with the chopped laminates. Core materials of the same variety as used in hand lay-up are easily incorporated.en

3.Filament Winding :





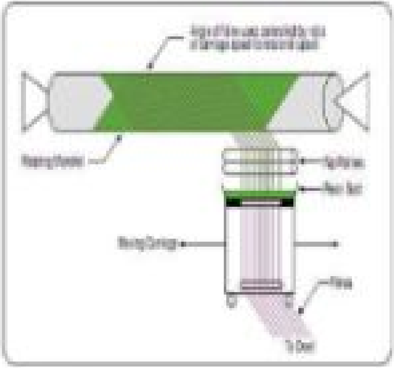
- Filament winding is an automated open molding process that uses a rotating mandrel as the mold.
- The male mold configuration produces a finished inner surface and a laminate surface on the outside diameter of the product.
- Filament winding results in a high degree of fiber loading, which provides high tensile strengths in the manufacture of hollow, generally cylindrical products such as chemical and fuel storage tanks, pipes, stacks, pressure vessels, and rocket motor cases.

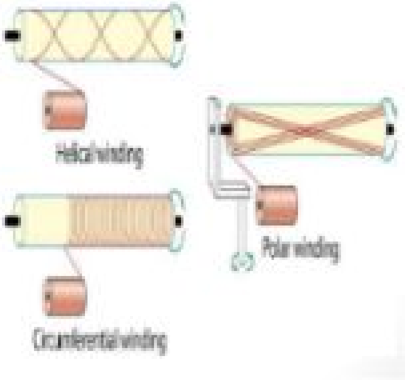
Filament-winding Process

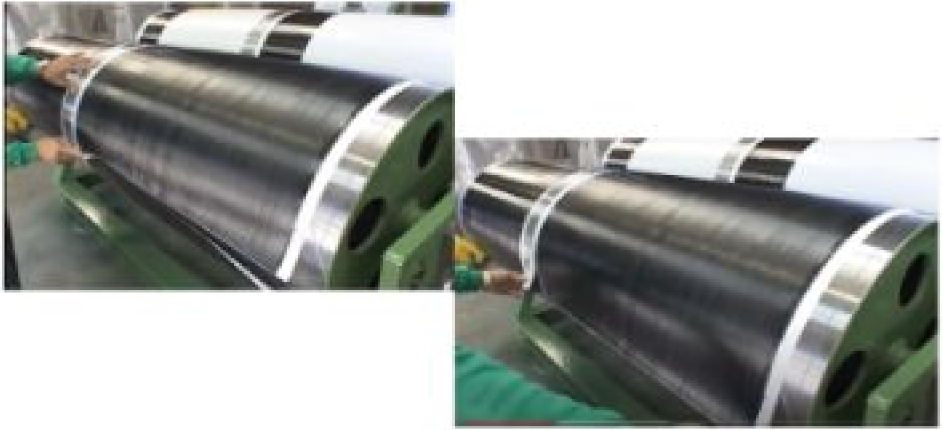
- Filament-winding process is a relative slowly with possibility to control the fiber direction and the diameter of parts can be varied along the part.
- During the process, roving or tape is drawn through a resin bath and wind in a rotational mandrel. Filament-winding mandrels may be metallic or non- metallic and assured the possibility of easy part removal or be dissolvable after curing.
- The fiber bundle has various dimensions, from several thousand of carbon fibers to several centimeters. The finished part is cured in an autoclave and later is removed from mandrel .
- **When the mandrel is removed, a hollow shape is the result. With this process can be realized variety parts as pipe, tubing, pressure vessels, tanks and items of similar shape. For enhance the structure of parts, the carbon fibers are wound with epoxy-resin systems.**

3.Filament Winding :

- Filament winding method involves a continuous filament of reinforcing material wound on to a rotating mandril in layers at different layers.
- If a liquid thermosetting (**denoting substances which set permanently when heated**)resin is applied on the filament prior to winding, the process is called the Wet Filament winding. If the resin is sprayed on to the mandrel with wound filament ,the process is called Dry Filament Winding.





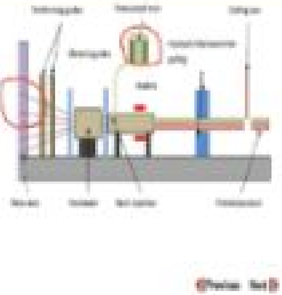


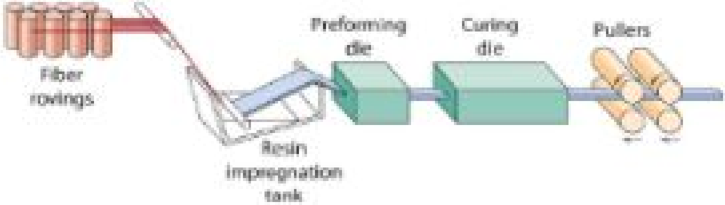
- Continuous strand roving is fed through a resin bath and wound onto a rotating mandrel. The roving feed runs on a trolley that traverses the length of the mandrel. The filament is laid down in a predetermined geometric pattern to provide maximum strength in the directions required. **When sufficient layers have been applied, the laminate is cured on the mandrel**. The molded part is then stripped from the mandrel. Equipment is available for filament winding on a continuous basis and two axis winding for pressure cylinders.

- Spray-up is an open mold method similar to hand lay-up in its suitability for making boats, tanks, transportation components and tub/shower units in a large variety of shapes and sizes.

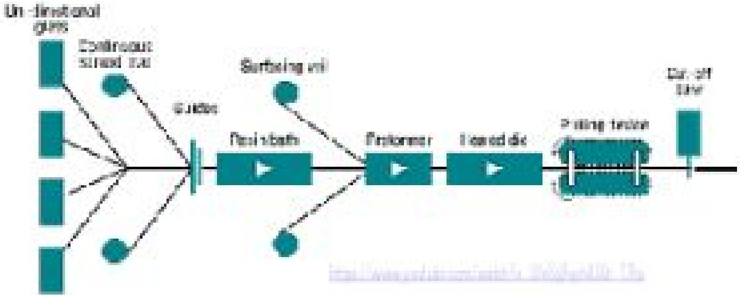
4.Pultrusion:

- It is a continuous process in which composites in the form of fibers and fabrics are pulled through a bath of liquid resin
- Then the fibres wetted with resin are pulled through a heated die. The die plays important roles like completing the impregnation and controlling the resin.

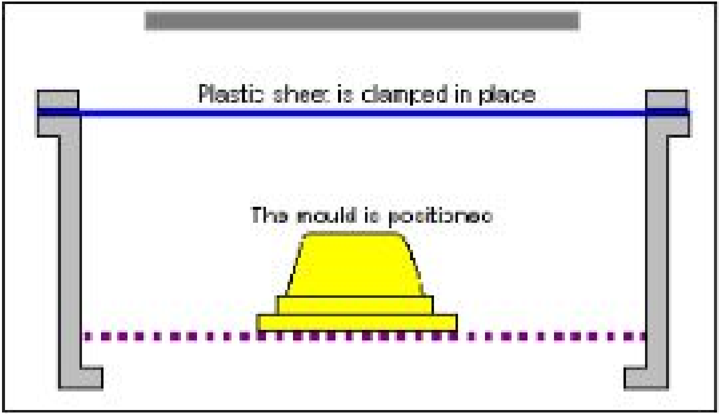




- Pultrusion is similar to extrusion in that it produces continuous cross-sectional profiles.
- **While extrusion relies on press to push unreinforced thermoplastic materials through a short die, pultrusion pulls a variety of reinforced fibers, wetted by thermosetting and/or some thermoplastic resins, through a heated die.**
- Polymerization of the resin occurs as the wetted fibers pass through the die, forming a continuous, rigid profile corresponding to the orifice shape.



5.Vaccum Bagging :

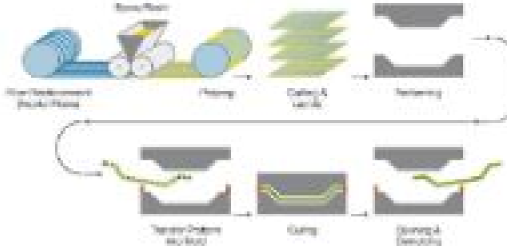


Vacuumforming is a simplified version of thermoforming, whereby a sheet of plastic is heated to a forming temperature, stretched onto a convex, or into a concave, single-surface mold, and forced against the mold by a vacuum (suction of air).

6.Prepeg: (a fibrous material pre-impregnated with a particular synthetic resin, used in making reinforced plastics)

Prepregs use phenolic, epoxy, and BMI resin matrices. They are normally reinforced with unidirectional and multiaxial, glass and carbon fibers. Hexcel's prepregs can meet a range of performance requirements such as good fatigue(weakness) performance, low temperature cure, fire/smoke/toxicity performance and temperature resistance.


Preparation and pre-forming of uncured materials
Laying up SMC and prepregs
Moulding and curing under heat and pressure
Demoulding of the cured part
SMC
Prepreg
SMC
Heated Press



How are Prepregs Manufactured?

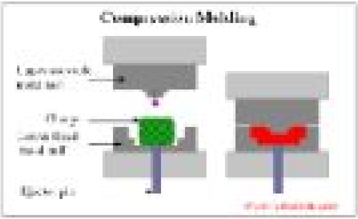
Prepregs are produced using two main processes: hot melt process and solvent dip process.

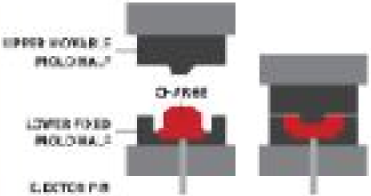
Hot Melt Process
Both fabric and unidirectional prepregs can be produced using the hot melt process. There are two stages in this process. **The first stage involves coating a thin film of the heated resin on a paper substrate. The reinforcement material and the resin are allowed to interact in the prepreg machine.** On application of pressure and heat, the resin is impregnated into the fibre resulting in the final prepreg, which is ultimately wound on a core.

Solvent Dip Process
Only fabric prepregs can be produced using the solvent dip process, which involves dissolving the resin in a solvent bath and dipping the reinforcing fabric in the resin solution. Using a drying oven, the solvent is then evaporated off the prepreg.

[illegible]

7.Compression Moulding:



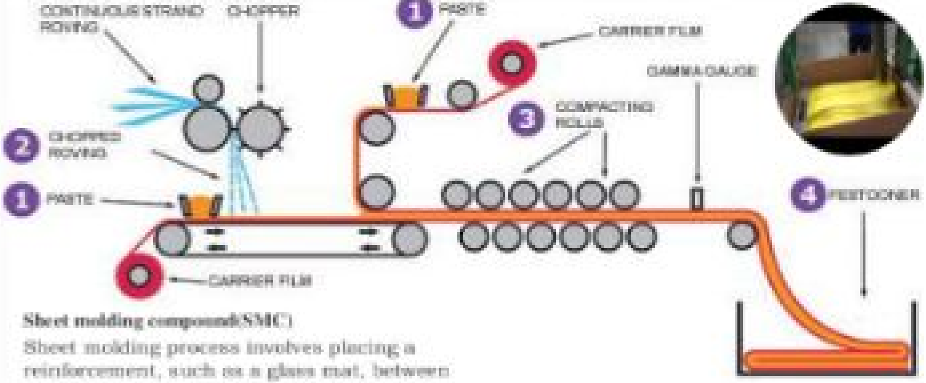


Compression molding is the most common process used with thermosetting materials and is usually not used for thermoplastics. With this process, **the material is squeezed into its desired shape with the help of pressure and heat. Plastic molding powder and other materials are added to the mix in order to create special qualities or to strengthen the final product. When the mold is closed and heated, the material goes through a chemical change that causes it to harden into its desired shape.** The amount temperature, amount of pressure, and length of time utilized during the process depends on the desired outcome.

Sheet Molding Process

- Sheet molding compounds (SMC) process is one of the main processing methods for fiber reinforced polymer composites.
- The process is currently used for wide range of structural and non structural composite parts especially in automobiles.
- The process offers ready to mold fiber reinforced polymer material which is preferably processed in compression molding.

8. Sheet Molding Compound:



Sheet molding compound(SMC)

Sheet molding process involves placing a reinforcement, such as a glass mat, between sandwiching layers of a thermoplastic and heating the materials to produce a single sheet of material.

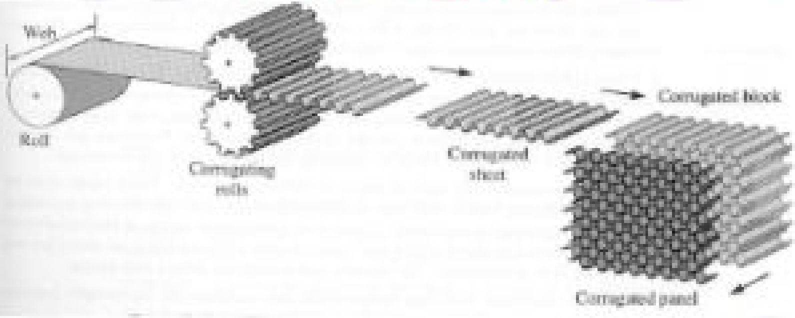
Bulk molding compound(BMC)

Bulk molding compounds by producing a billet of molten material that is placed into a compression molding press which molds the molten material into a part.

Laminating Process

- The laminating process is large used **at fabrication of advanced materials**. To improve the process it can be used a **prepreg material**, which is a **preimpregnated reinforced material with high composite's property by fibers aligned parallel to each other**.
- A sample of product's form is cut off by variety proceedings and the prepreg (***Prepreg*"** *is the common term for a reinforcing fabric which has been pre-impregnated with a resin system).* material is fixed into desired laminate geometry. **The final workpiece is achieved by curing the stacked plies under pressure and heat in an autoclave**.
- For examples, the graphite-epoxy composite is cured at aprox.1800C and at pressure of 0.7MPa, and for high-temperature composite such as bismaleimides the cured temperature is of 3200C. The tooling is requested a mold following a part through the lay-up and autoclaving process. As material tooling for fabrication of composites are aluminum, steel, electroplated nickel, a high-temperature epoxy-resin system casting, etc
- The productivity of manual lay-up can be improved by used an automated process by CNC machines, with large applications in aerospace and automotive industry.

Sandwich Structures

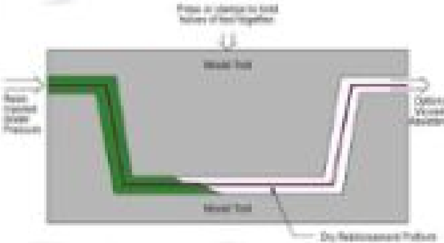


In the corrugation method for producing a honeycomb core, the material such as Al is corrugated between two rolls, which are joined together with adhesive and then cut to the desired thickness. The plastic deformation will work harden the Al.

9.Resin Transfer Molding Process

- This process represents **a completion between hand manufacturing lay-up or spray-up of parts and compression molding in matched metal molds .**
- In resin transfer molding (RTM) process, **a set of mold halves are loaded with reinforcement material then clamped together. Resin is then pumped, or gravity fed into the mold infusing the reinforcement material.**
- Once the mold is filled with resin, it is plugged and allowed to cure. After curing, the mold halves are separated and the part removed for final trimming and finishing.
- The RTM permits faster cycle times and required less work as spray-up method. The cycle times of RMS are longer than for compression molding, but low tooling cost get compensation, in special for a low production.
- Resin transfer molding produces large, complex items such as bath and shower enclosures, cabinets, aircraft parts, and automotive components.

RTM- Resin Transfer Molding



- Fabrics or preforms are laid up as a dry stack of materials. A second mould tool is then clamped over the first, and resin is injected into the cavity. Vacuum can also be applied to the mould cavity to assist resin in being drawn into the fabrics.
-
- Pros: High fiber volume low void contents.) Good environmental control due to enclosure of resin. Both sides of the component have a moulded surface.
- Cons: Matched tooling is expensive, and heavy, Generally limited to smaller components. Unimpregnated areas can occur
- Applications: Small complex aircraft and automotive components, train seats

As processing of composite materials are used the injection molding that is widely automated and vacuum bagging, autoclave cure process, which is a hand lay- up or an automated tape lay-up that must be cured by a combination of heat, pressure, vacuum, and inert atmosphere.

The selection of adequate process of composites is made by some rules, such as type of composites, applications, quality parts, size of production, costs, etc.

Composite Combinations

Composite can be classified into three basic types. They are:

PMC - Polymer Matrix Composites

- By far the most common type of composite material.
- Matrix is relatively soft and flexible.
- Reinforcement must have high strength and stiffness
- As the load must be transferred from matrix to reinforcement, the reinforcement-matrix bond must be strong.

CMC - Ceramic Matrix Composites

- Matrix is relatively hard and brittle
- Reinforcement must have high tensile strength to arrest crack growth

MMC - Metal Matrix Composites

- Matrix is relatively soft and flexible.
- Reinforcement must have high strength and stiffness
- As the load must be transferred from matrix to reinforcement, the reinforcement-matrix bond must be strong.
- MMC composites use three basic types of particulates or fibers:
  1) Dispersion strengthened alloys
  2) Regular particulate composites
  3) Long fiber reinforcements

METAL MATRIX MATERIAL

Common Metal Matrices:

Metal matrices include aluminum, magnesium, copper, nickel, and intermetallic compound alloys

MMCs are better at higher temperatures than PMCs although production is much more difficult and expensive

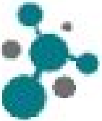
MMCs can have applications such as fan blades in engines, clutch and brake linings, engine cylinder liners, etc.

Manufacturing Techniques

- Reinforcement and Matrix may be composed during manufacturing of the part

- Reinforcement and Matrix may come composed as layers called Prepregs

  - Prepreg: an assembly of reinforcement impregnated with resin, prepared for preforming into a composite shape before the curing process used to set the resin.

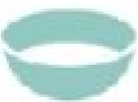


Polymer Matrix Composites

Material having Polymer as a matrix material in composites is called a Polymer matrix composite.

Properties

- Ease of Fabrication
- Lower cost
- Polymer phase increases
  - Elastic Modulus
  - Yield Strength
  - Tensile Strength
  - Creep Resistance



Ceramic Matrix Composite

Material having Ceramic as a matrix material in composites is called a ceramic matrix composite.

Properties

- High strength
- Hardness
- High service temperature
- Chemical inertness
- Low density

Metal Matrix Composites

Material having Metal as a matrix material in composites is called a Metal matrix composite.

- High Tensile Strength
- High Specific Gravity
- High Toughness (For Large diameter Fiber)
- High Creep Resistance
- High Elastic Modulus

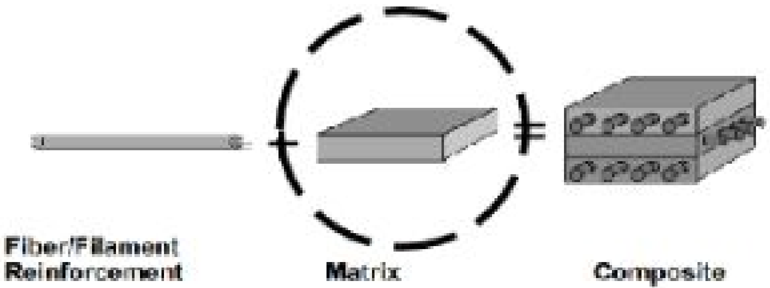
FACTORS AFFECTING MICROSTRUCTURE AND PROPERTIES OF COMPOSITES

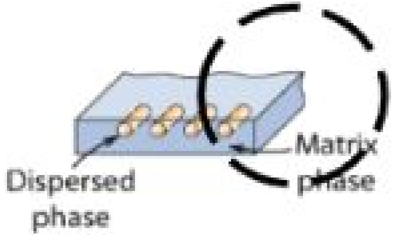
- Type of Reinforcement
- Reinforcement size and its Orientation
- Matrix Type
- Fiber Volume Fraction (FVF)
- Direction of loading
- Bonding between Reinforcement and matrix

WHAT ARE THE ADVANTAGES OF COMPOSITE MATERIALS?

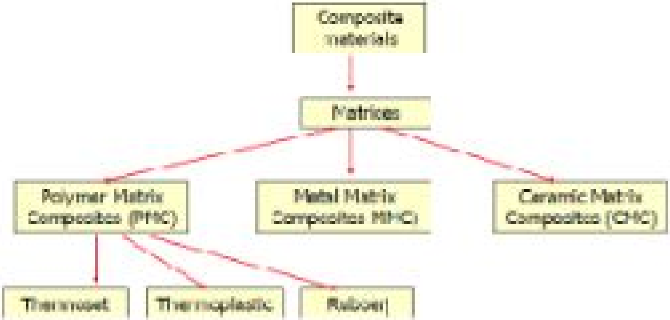
- Low costs compared to metals
- Design flexibility
- Resistance to a wide range of chemical agents
- Low weight
- Durability
- Electric insulation
- High impact strength

MATRIX PHASE :





Classification based on Matrices



Matrix material serves several functions in the composite

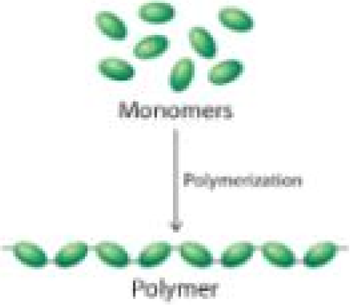
- Provides the bulk form of the part or product
- Holds the imbedded phase in place
- Shares the load with the secondary phase

POLYMER

- A large molecule (macromolecule) composed of repeating structural units (monomer) typically connected by covalent chemical bonds.

POLYMER MATRIX COMPOSITE (PMC)

- Consisting of a polymer (resin) matrix and fiber.
- Very popular due to their low cost and simple fabrication methods.



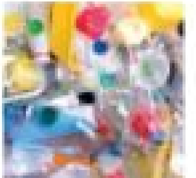
Polymer Matrix Composites (PMCs) :

•Thermosetting (A thermosetting plastic is a polymer that irreversibly becomes rigid when heated. Such a material is also known as a thermoset) or thermosetting resins are the most widely used polymers in PMCs.

- Epoxy and polyester are commonly mixed with fiber reinforcement
  - Polymer Matrix Composites
  - In PMCs polymer is the primary phase in which a secondary phase is imbedded as fibers, particles, or flakes.

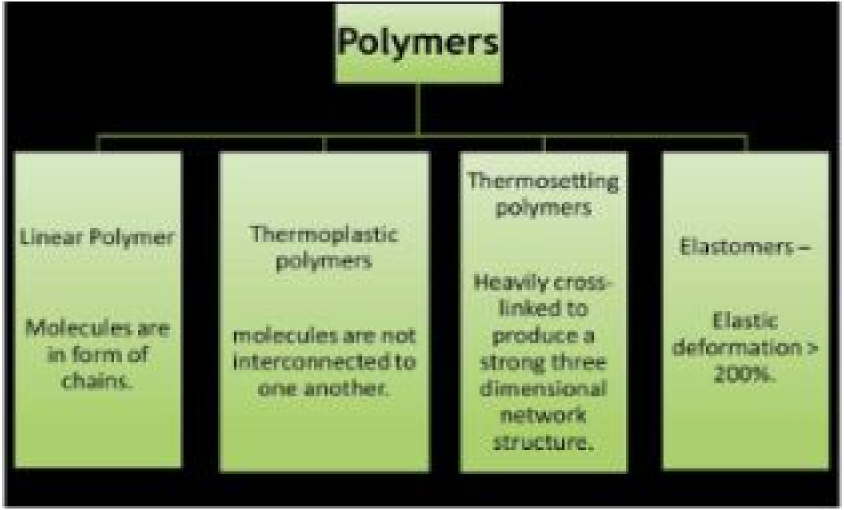
- **Low density, high specific strength, high specific stiffness, ease of fabrication.**

- Examples: Rubber reinforced with carbon black and fiber-reinforced plastic (FRPs) Commercially, PMCs are more important than MMCs or CMCs .



Plastics are typically organic polymers

CLASSIFICATION OF POLYMERS :



THERMOSETTING POLYMER Extensive cross linking formed by covalent bonds

- High Thermal stability.
- High dimensional stability.
- Low weight.
- High rigidity.
- Can not be recycled due to its heavy co

THERMOPLASTICS: No chemical linking between individual molecules.

- Molecules are bonded by weak
- secondary bonds like Van der walls bonds and hydrogen.
- Parts can be made and joined by heating.
- Can be remolded, and recycled.

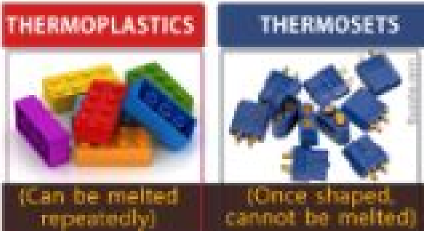
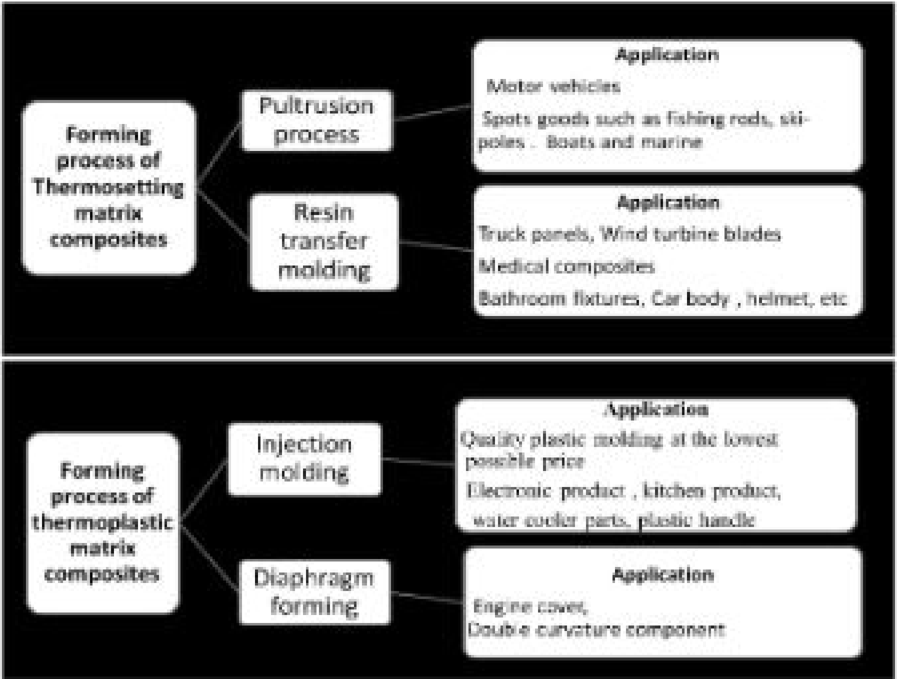


Figure 3. Thermosetting Plastic

Figure 4. Thermal degradation


Forming process of Thermosetting matrix composites
Pultrusion process
Application
Motor vehicles
Spots goods such as fishing rods, ski-poles . Boats and marine
Resin transfer molding
Application
Truck panels, Wind turbine blades
Medical composites
Bathroom fixtures, Car body , helmet, etc
Forming process of thermoplastic matrix composites
Injection molding
Application
Quality plastic molding at the lowest possible price
Electronic product , kitchen product, water cooler parts, plastic handle
Diaphragm forming
Application
Engine cover,
Double curvature component

APPLICATION IN CONSTRUCTION

A potentially high-volume market for PMCs lies in construction applications especially in Construction of

- Buildings
- Bridges
- Housing
- Lampposts
- Smokestacks
- Highway culverts.

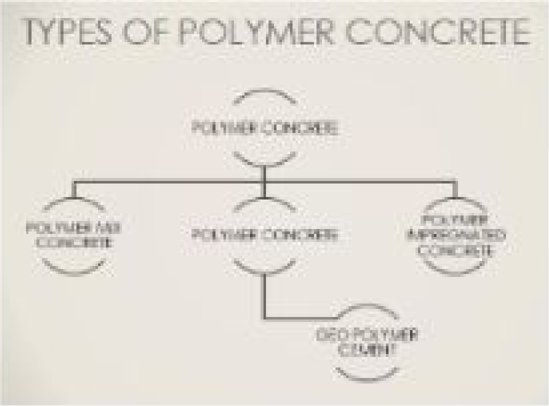
LIMITATIONS OF PMC

- Low maximum working temperature.
- Sensitivity to radiation and moisture.
- Processing temperature are generally higher than those with thermosets.
- Required special processing equipment.
- Thermoset resins have poor impact resistance.

ADVANTAGES OF PMC :

- Good inplane stiffness and strength.
- Low density.
- Relatively low cost.
- Corrosion resistance.
- Low coefficient of thermal expansion.
- Relatively mature technology.
- Excellent in-service experience.

POLYMER CONCRETE :




PROPERTIES
INCREASE
DENSITY
PERMEABLITY
DURABILITY
COMPRESSIVE STRENGTH
TENSILE STRENGTH
POROSITY
CORROSION
VOIDS
CRACKS
DECREASE

WOOD POLYMER COMPOSITE

Composed of....

- Rice/Wheat Husk
- Thermoplastic

(Rice/Wheat Husk for Durability)

(Thermoplastic for Flexibility)

A Promising and Sustainable Green Material that is Produced for its

a) Ability to be Durable without Containing Toxic Chemicals
b) Improve Energy Efficiency

MAJOR STRENGTH OF WPC

- 100% "TERMITE" and "BORERS Proof
- Water Proof Guarantee
- Fire Retardant
- WPC is Highly Durable and Requires
- Low Maintenance and multi purpose products.

INDUSTRY DEMANDS

- Modular Kitchen ,Façade Cladding ,Wall Cladding ,Partition Panels
- Ceiling ,Shuttering ,Flooring,House Hold Furniture.

MATRIX & REINFORCEMENT MATRIX

- Thermosetting polymers are the most common matrix materials

  –Principal TS polymers are:

- Phenolics – used with *particulate reinforcing phases*
- Polyesters and epoxies - *most closely associated with FRPs*
- Nearly all rubbers are reinforced with carbon black

REINFORCEMENT

Possible geometries - (a) fibers, (b) particles & (c) flakes
Particles and flakes are used in many plastic molding compounds Of most engineering interest **is the use of fibers as the reinforcin phase in FRPs** .

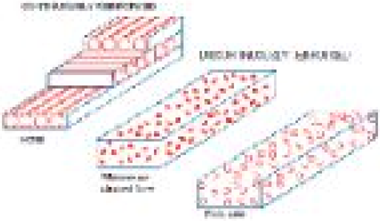
(a) (b) (c)

THE REINFORCING PHASE

- The imbedded phase is most commonly one of the following shapes:
  - Fibers, particles, flakes
- Orientation of fibers:

- **One-dimensional:** maximum strength and stiffness are obtained in the direction of the fiber.
- **Planar:** in the form of two-dimensional woven fabric.
- **Random or three-dimensional:** the composite material tends to posses isotropic properties

1. FIBRE REINFORCED COMPOSITES (FRP)
2. Continuous fibre reinforced composites
3. Discontinuous fibre reinforced composites



PLACES OF APPLICATION

- hazardous waste containment,drains,manholes,acid tanks
- swimming pools, tunnel lining, shells, floor tiles,
- 70–75% of its strength after a curing of one day at room temperature
- The early strength gain is important in precast applications because it permits the structures to resist higher stresses early due to form-stripping, handling, transportation, and erection operations
- Quick setting time
- Environmental safety

NATURAL FIBRE REINFORCED POLYMER

Commonly used natural fibres are coir, jute, bagasse, cotton, bamboo, hemp which come from plants.

NFRP are :

- eco-friendly
- light weight
- strong
- renewable
- cheap
- biodegradable

Coconut shell	walnut shells	Rice husk
Coconut shell powder	walnut shells powder	Rice husk powder

It can be used to reinforced both thermosetting and thermoplastic matrices.

ADVANTAGES:

- low density
- Low cost
- Low energy inputs
- Comparable mechanical properties
- Better elasticity

TYPES OF FRP

- Carbon Fibres
- Glass Fibres
- Fibres in matrix

CARBON FIBER

- Thin strands of carbon- even thinner than human hair.
- Strands can be twisted together, like yarn- can be woven together, like
- cloth extremely lightweight.

FIBER GLASS

- Fiberglass is a lightweight, extremely strong, and robust material.

- Fiberglass combines its light weight with an inherent strength to provide a weather resistant finish with a variety of surface textures.

FRP ADVANTAGES

- It has long working life.
- It's density is less than density of steel.
- It is insensitive to change in temperature.
- It's properties is much better than any of the other metals.
- It's compressive strength is greater than all the reinforcing material.

DISADVANTAGE

- It is very costly.
- It is little bit harmful for the human body as it cause some form of cancer of the lungs.

APPLICATIONS

- It is mostly used in aerospace and aircraft industries
- Automotive body is also made up of the carbon fiber.
- It is used in making sports epuipment such as light weight badminton & rackets, golf stick ...
- Constructing up of wind mill blades.
- It is used for building and construction material.
- Rechargeable battries and fuel cell electrodes.
- Portable powers.

GENERAL PROPERTIES:

- High Strength-to-weight ratio
  Corrosion Resistance
- Wear Resistance
- Greater fatigue Life
- Low electrical conductivity
- Anisotropic (Anisotropy is the property of a material which allows it to change or assume different properties in different directions as opposed to isotropy)
- Lower cost
- Easy processing
- Covers almost all application areas

CERAMIC MATRIX COMPOSITES:

- Ceramic matrix composites (CMCs) are a subgroup of composite material as well as a subgroup of technical ceramic.
- They consist of ceramic fibers embedded in a ceramic matrix, thus forming a ceramic fiber reinforced ceramic (CFRC) material.

PRODUCTION OF CERAMIC MATRIX COMPOSITES:

- Ceramic composites may be produced by traditional ceramic fabrication methods including mixing the powdered matrix material with the reinforcing phase followed by processing at elevated temperature: hot pressing ,sintering.

- Such fabrication routs are successfully employed for preparing composites reinforced with a discontinuous phase.

CERAMIC COMPOSITE

- The best strengthening effect is provided by dispersed phase in form of continuous monofilament fibers, which are fabricated by chemical vapor deposition (CVD) of silicon carbide on a substrate made of tungsten (W) or carbon (C) fibers.
- Monofilament fibers produce stronger interfacial bonding with the matrix material improving its toughness.
- Failure of long-fiber Ceramic Matrix Composites is not catastrophic.

METAL MATRIX COMPOSITES (MMCs)

- A metal matrix composite (MMC) is composite material with at least two constituent parts, one being a metal.

- The other material may be a different metal or another material, such as a ceramic or organic compound.

- When at least three materials are present, it is called a hybrid composite.

COMPOSITION

- MMCs are made by dispersing a reinforcing material into a metal matrix. The reinforcement surface can be coated to prevent a chemical reaction with the matrix.

- For example, carbon fibers are commonly used in aluminum matrix to synthesize composites show.

MATRIX

- The matrix is the monolithic material into which the reinforcement is embedded, and is completely continuous.

- This means that there is a path through the matrix to any point in the material, unlike two materials sandwiched together.

- The matrix is usually a lighter metal such as aluminum, magnesium, or titanium, and provides a compliant support for the reinforcement.

REINFORCEMENT

- The reinforcement material is embedded into the matrix.

- It is used to change physical properties such as wear resistance, friction coefficient, or thermal conductivity.

- The reinforcement can be either continuous, or discontinuous.

Metal Matrix Composites

Material having Metal as a matrix material in composites is called a Metal matrix composite.

- High Tensile Strength
- High Specific Gravity
- High Toughness (For Large diameter Fiber)
- High Creep Resistance
- High Elastic Modulus

CONCLUSION :
FUTURE ASPECTS OF COMPOSITE MATERIALS :

- There is a shift developing more prominently towards Green Engineering.
- Our environment is given increased thought and attention by today's society. This is true for composite material manufacture as well.
- Composites have a lighter weight and similar strength values as heavier materials. When the lighter composite is transported, or is used in a transport application, there is a lower environmental load compared to the heavier alternatives.
- Composites are also more corrosion-resistant than metallic based materials, which means that parts will last longer. These factors combine to make composites good alternate materials from an environmental perspective.

- Conventionally produced composite materials are made from petroleum based fibres and resins, and are non-biodegradable by nature.This presents a significant problem as most composites end up in a landfill once the life cycle of a composite comes to an end.There is significant research being conducted in biodegradable composites which are made from natural fibres.

- The discovery of biodegradable composite materials that can be easily manufactured on a large-scale and have properties similar to conventional composites will revolutionize several industries, including the aviation industry.

- An alternative option to aid environmental efforts would be to recycle used parts from decommissioned aircraft. The 'unengineering' of an aircraft is a complex and expensive process, but may save companies money due to the high cost of purchasing first-hand parts.

1.What is a composite Material ??

- A composite material is a combination of two materials with different physical and chemical properties.

2.Why should we go for a composite Material ??

▪The reason for their use over traditional materials is because they improve the **properties of their base materials and are applicable in many situations. Such as lessen the weight but increase its strength.**

HIGH STRENGTH : LOW WEIGHT RATIO

3.What are the two phases of a composite Material ??

- Dispersed phase.
- Matrix phase

5.state the two examples of a composite Material from day to day to day life ??

- Wood
- Bones
- Straw bricks

6.What are the subdivisions of a filament / dispersed phase??

- PARTICULATE
- FIBRE
- LAMINATE

7.QUOTE AN EARLY EXAMPLE OF A COMPOSITE MATERIAL??

- BOW MADE FROM BONE,CATTLE TENDONS COMBINED WITH RESIN

8.QUOTE AN EARLY EXAMPLE OF A COMPOSITE MATERIAL??

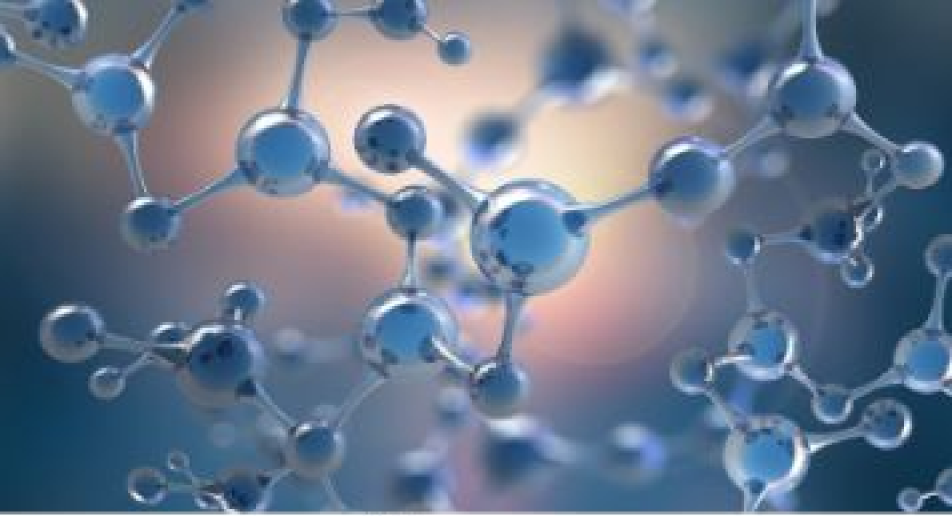

Information

Composite Manufacturing Process:

http://www.youtube.com/watch?v=[illegible]

Unit -4

NANO MATERIALS



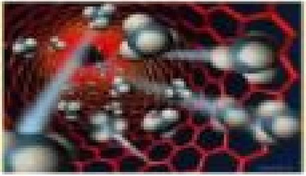
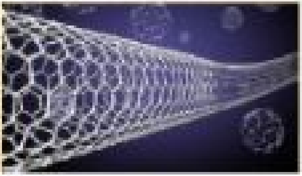
UNIT-4

Definition, manufacture and types of nano materials. Properties, performance of nano materials in building construction, types application of nano-materials like carbon, nanotubes etc.,

Nano composite used with cement, steel, aluminium, wood, glass for thermal insulation, fire protection, coating and painting and structural monitoring etc.Nano technologies in building and construction.

INTRODUCTION:

- Nanomaterials are **cornerstones** of nanoscience and nanotechnology.
- Nanostructure science and technology is a **broad and interdisciplinary area of research and development activity that has been growing explosively worldwide in the past few years.**
- It has the potential for revolutionizing the ways in which materials and products are created and the range and nature of functionalities that can be accessed.
- It is already having a significant commercial impact, which will assuredly increase in the future.
- **Nanotechnology holds a promise and creates great opportunities for advancing construction systems, building materials, and design methods.**
- **Potential applications in high-rise construction, reinforced concrete, cement products as well as pavement engineering have been noted by various studies.**

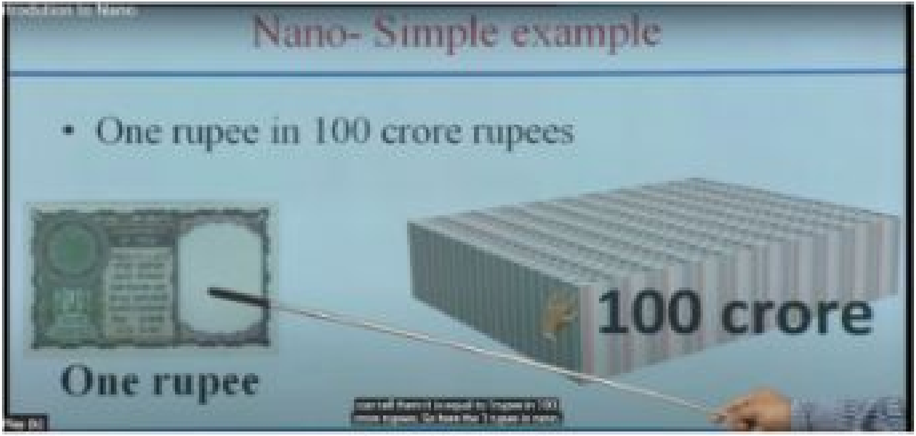
What is a nanoparticle?

- Nanoparticle is any material having atleast one of its dimensions in the range of 1-100 nm
- "Nano" – derived from a Greek word "Nanos" meaning DWARF or small.
- 'Nono Taniguchi, 1974' – coined the term nanotechnology
- A nanometer is *one billionth of a meter* (10^{-9} m).


Comparison of macro, micro and nanoscale
Macro
Micro
Nano

Nano- Simple example

- The population of India is one billion or 100 crores. Each Indian – you or me is nano in comparison with the total population of India.



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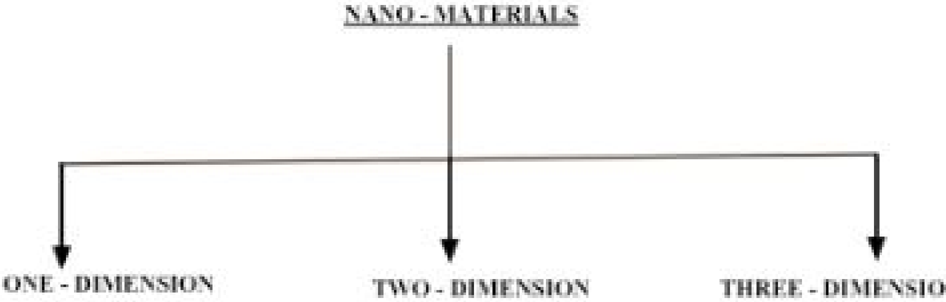
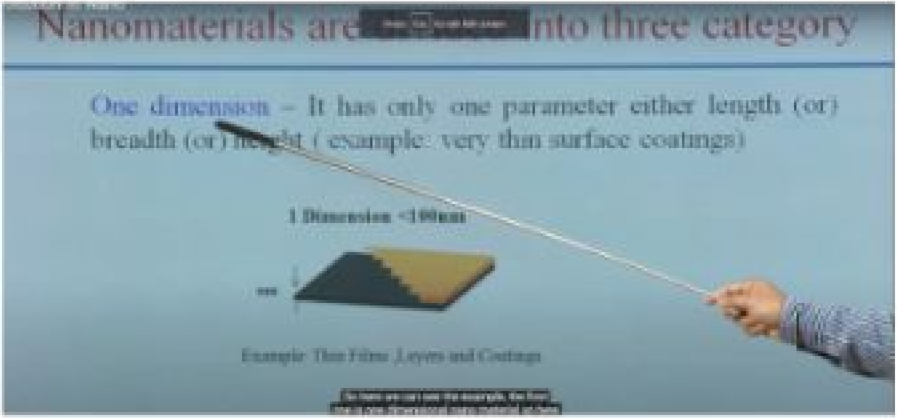

NANO - MATERIALS
ONE - DIMENSION
TWO - DIMENSION
THREE - DIMENSIO


Nanomaterials are [redacted] nto three category
One dimension – It has only one parameter either length (or) breadth (or) height (example: very thin surface coatings)
1 Dimension <100nm
Example: Thin Films ,Layers and Coatings

Nanomaterials are divided into three category

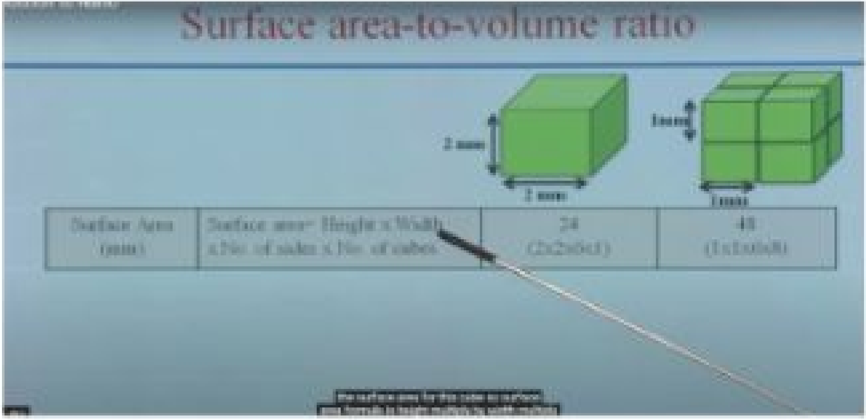
Two dimensions- it has only length and breadth (for example, nanowires and nanotubes)

2 Dimension <100nm

Example: Nanotubes, Nano fibers and Nanowires


Nanomaterials are divided into three category
Three dimensions -it has all parameter of length, breadth and height (for example, Nano Particles).
3 Dimension <100nm

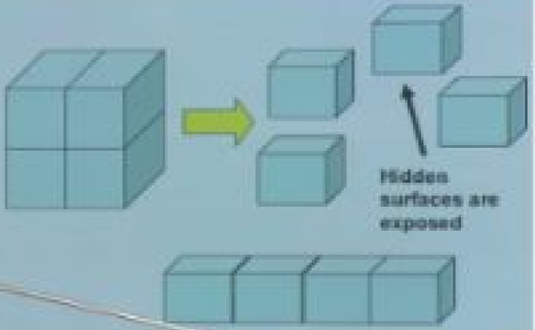

Why small is good?



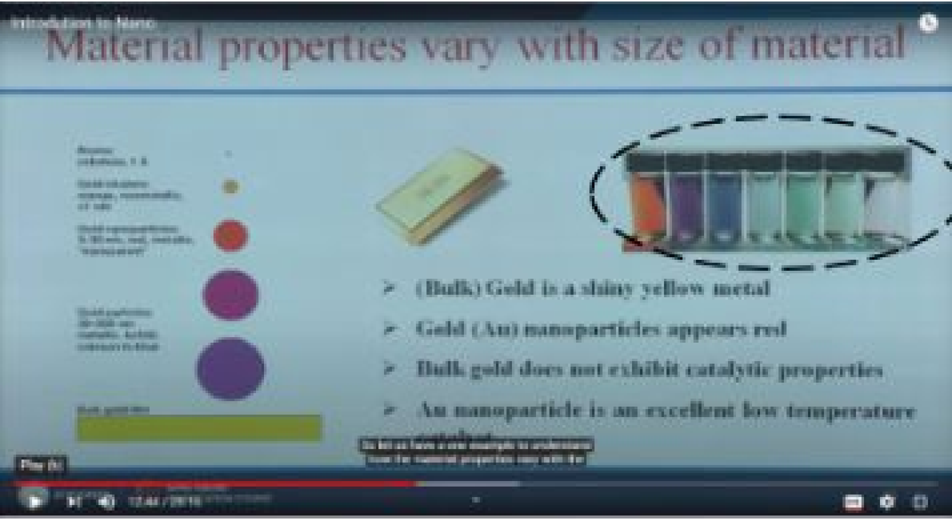
https://www.youtube.com/watch?v=k61wja
b7iUs

Surface area-to-volume ratio

- As surface to volume ratio increases
- A greater amount of a substance comes in contact with surrounding material
- This results in better catalysts, since a greater proportion of the material is exposed for potential reaction



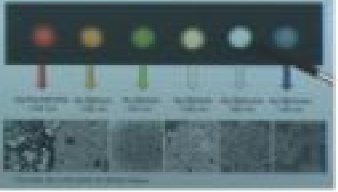
When the surface area goes down , it has very good interactivity



The change in color happens due to Surface plasma reasonance.

Nanoscale size effect

- Manifestation of novel phenomena and properties, including changes in:
  - Physical Properties (e.g. melting point)
  - Chemical Properties (e.g. reactivity)
  - Electrical Properties (e.g. conductivity)
  - Mechanical Properties (e.g. strength)
  - Optical Properties (e.g. light emission)



What are Nanomaterials ??

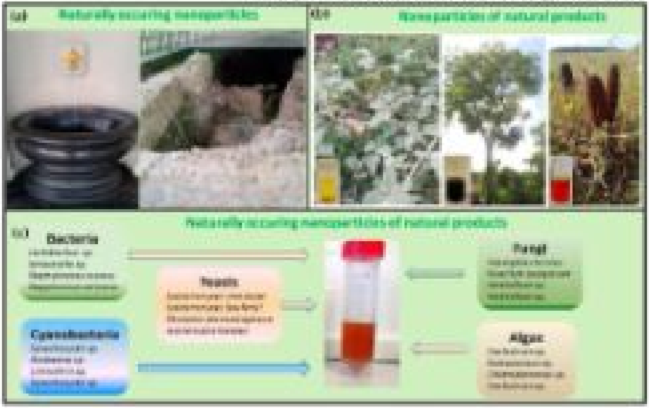
- Nanomaterials can be defined as materials possessing, at minimum, one external dimension measuring 1-100nm.

- The definition given by the European Commission states that the particle size of at least half of the particles in the number size distribution must measure 100nm or below.

- **Nanomaterials can occur naturally, be created as the by-products of combustion reactions, or be produced purposefully through engineering to perform a specialised function.**

- These materials can **have different physical and chemical properties to their bulk-form counterparts.**

What are Naturally Ocurring Nanomaterials ??



Examples of natural and biological materials which contain nanoscopic particles.
(a) **Naturally occurring nanoparticles of inorganic, elemental sulfur, for instance, are found at mineral wells rich in hydrogen sulfide, such as the Elisenbrunnen in Aachen.**
(b) In contrast, mechanically produced **nanomaterials of natural products have been evaluated for medical and agricultural applications.**
(c) Eventually, there are also naturally produced **nanomaterials of natural, biological products, such as nanoscopic particles of elemental selenium coated with microbial proteins which are formed by bioreductive or oxidative metabolism in bacteria and fungi.**

Uses of created Nanomaterials :

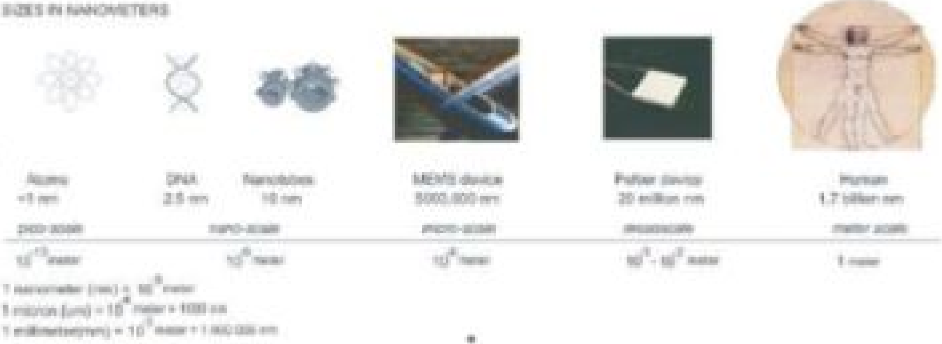
- The healthcare field, utilises nanomaterials in a variety of ways, with one major use being drug delivery.
- One example of this process is whereby nanoparticles are being developed to assist the transportation of chemotherapy drugs directly to cancerous growths, as well as to deliver drugs to areas of arteries that are damaged in order to fight cardiovascular disease.
- Carbon nanotubes are also being developed in order to be used in processes such as the addition of antibodies to the nanotubes to create bacteria sensors.

Uses of created Nanomaterials :

- In aerospace, carbon nanotubes can be used in the morphing of aircraft wings. The nanotubes are used in a composite form to bend in response to the application of an electric voltage.
- Elsewhere, environmental preservation processes make use of nanomaterials too - in this case, nanowires.
- Applications are being developed to use the nanowires - zinc oxide nanowires- in flexible solar cells as well as to play a role in the treatment of polluted water.

What are Nano materials ?

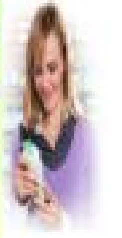
- **Nanoscale materials are defined as a set of substances** where at least one **dimension is less than approximately 100 nanometers**.
- A nanometer is one millionth of a millimeter – approximately 100,000 times smaller than the diameter of a human hair.
- Nanomaterials are of interest because at this scale unique optical, magnetic, electrical, and other properties emerge. These emergent properties have the potential for great impacts in electronics, medicine, and other fields



WHERE ARE NANOMATERIALS FOUND?

- Naturally occuring nanostructures are present in volcanicash, ocean spray
- .fine sand and dust. Also present in plants and animals.
- For example-nanostructure ensures an antireflection and water repelling effect so they can fly safely.
- Nowadays, scientist can create **nanostructure themselves by rearranging the atoms of an object , they can make new nanomaterial with new properties.**
- That are **stronger, lighter or different in colour.**
- **Some nanomaterials occur naturally , but of particular interest are engineered nanomaterials, which are designed for , and already being used in many commercial products and processes.**
- They can be found as **sunscreens , cosmetics , stain resistant clothing, tires**
- **.electronics as well as in medicine purposes of diagnostic ,imaging and drug delivery.**



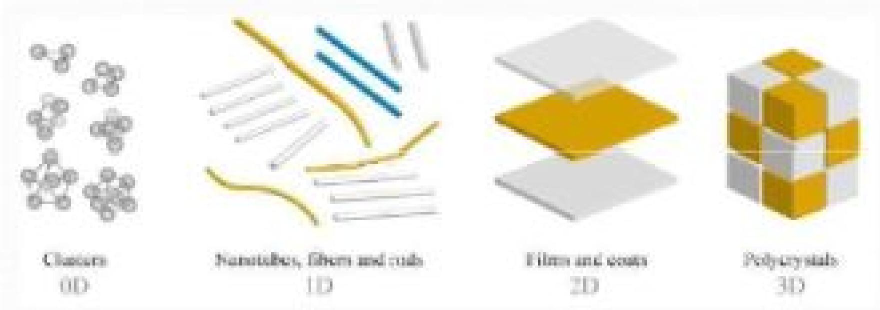


History of nanomatrials

CURRENT APPLICATIONS:

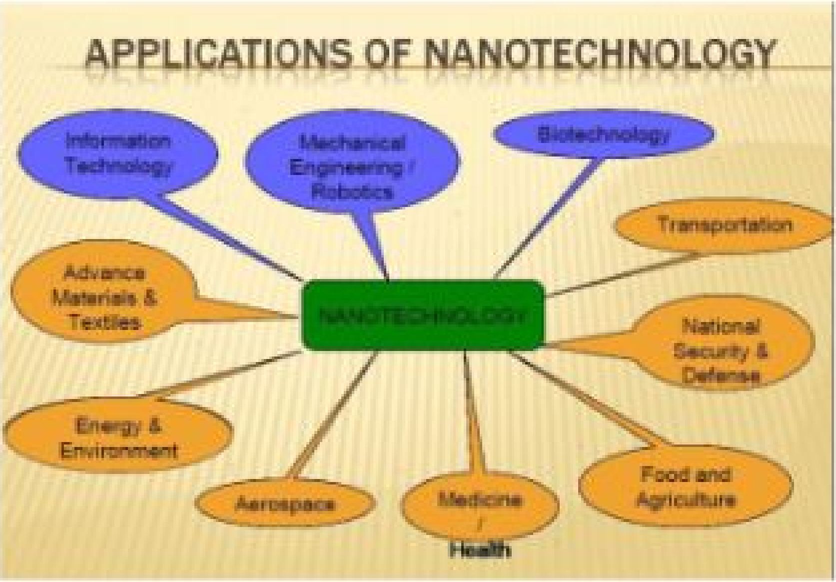
- Water filtration devices, paints, cosmetics, coatings, lubricants, textiles, memory/storage devices
- Medical diagnostics, displays, sensors, drug delivery, composite materials, solid state lighting, bio-materials, nano arrays, more powerful computers, protective armor, chembio suits, and chem-bio sensors.

TYPES OF NANOSTRUCTURES:



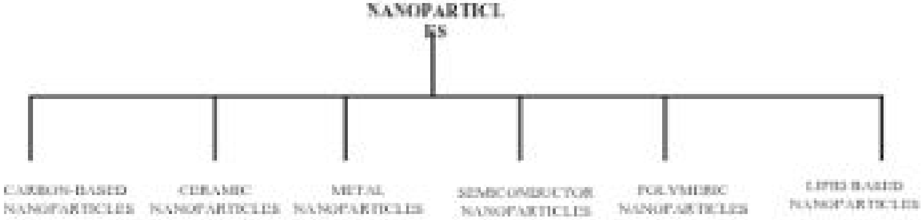
MATERIALS AT NANOSCALE CAN HAVE DIFFERENT PROPERTIES

- **Nanomaterials have a much greater surface area to volume ratio , which can lead to greater chemical reactivity and affect their strength**
- **Also at nano scale, quantum effects can become much more important in determining the materials properties and characteristics, leading to novel optical, electrical and magnetic behaviours.**


APPLICATIONS OF NANOTECHNOLOGY
Information Technology
Mechanical Engineering / Robotics
Biotechnology
Transportation
Advance Materials & Textiles
NANOTECHNOLOGY
National Security & Defense
Energy & Environment
Aerospace
Medicine / Health
Food and Agriculture

DIFFERENT TYPES OF NANOPARTICLES

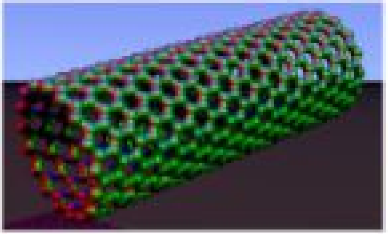
Nanoparticles can be classified into different types according to the size, morphology, physical and chemical properties.

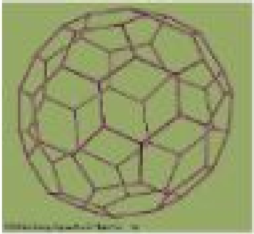


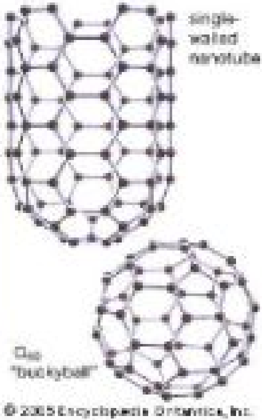
CARBON BASED NANO PARTICLES :

- Carbon-based nanoparticles include two main materials: **carbon nanotubes (CNTs) and fullerenes. CNTs are nothing but graphene sheets rolled into a tube.** Fullerene, also called buckminsterfullerene, any of a series of hollow carbon molecules that form either a closed cage ("buckyballs") or a cylinder (carbon "nanotubes").
- These materials are mainly used for the structural reinforcement as they are 100 times stronger than steel.
- CNTs can be classified into single-walled carbon nanotubes (SWCNTs) and multi-walled carbon nanotubes (MWCNTs).
- CNTs are unique in a way as they are thermally conductive along the length and non-conductive across the tube.
- **Fullerenes are the allotropes of carbon having a structure of hollow cage of sixty or more carbon atoms.**
- **The structure of C-60 is called Buckminsterfullerene, and looks like a hollow football.**
- The carbon units in these structures have a pentagonal and hexagonal arrangement. These have commercial applications due to their **electrical conductivity, structure, high strength, and electron affinity.**

https://interestingengineering.com/3-amaz ng-uses-carbon-nanotubes

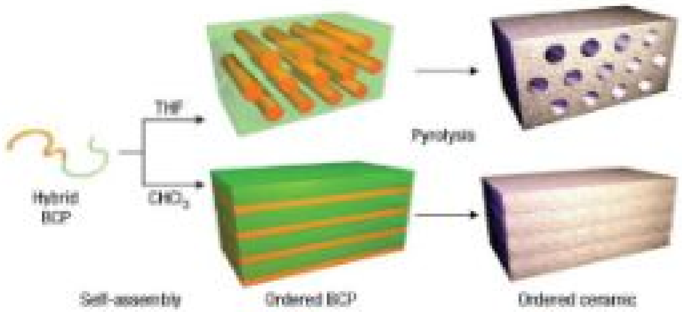





single-walled nanotube
"buckyball"
© 2005 Encyclopædia Britannica, Inc.

CERAMIC NANO PARTICLES :

- Ceramic nanoparticles are inorganic solids made up of oxides, carbides, carbonates and phosphates. These nanoparticles have high heat resistance and chemical inertness.
- They have applications in photocatalysis, photodegradation of dyes, drug delivery, and imaging.
- By controlling some of the characteristics of ceramic nanoparticles like size, surface area, porosity, surface to volume ratio, etc, they perform as a good drug delivery agent.
- These nanoparticles have been used effectively as a drug delivery system for a number of diseases like **bacterial infections, glaucoma, cancer, etc.**



METAL NANO PARTICLES :

- Metal nanoparticles are prepared from metal precursors. These nanoparticles can be synthesized by chemical, electrochemical, or photochemical methods.
- In chemical methods, the metal nanoparticles are obtained by reducing the metal-ion precursors in solution by chemical reducing agents.
- These have the ability to adsorb small molecules and have high surface energy.
- These nanoparticles have applications in research areas, detection and imaging of biomolecules and in environmental and bioanalytical applications.

SEMICONDUCTOR NANOPARTICLES:

- Semiconductor nanoparticles have properties like those of metals and non- metals. They are found in the periodic table in groups II-VI, III-V or IV-VI.

These particles have wide bandgaps, which on tuning shows different properties. They are used in photocatalysis, electronics devices, photo- optics and water splitting applications.

POLYMERIC NANOPARTICLES:

- Polymeric nanoparticles are organic based nanoparticles. Depending upon the method of preparation, these have structures shaped like nanocapsular or nanospheres.
- A nanosphere particle has a matrix-like structure whereas the nanocapsular particle has core-shell morphology. In the former, the active compounds and the polymer are uniformly dispersed whereas in the latter the active compounds are confined and surrounded by a polymer shell.
- Some of the merits of polymeric nanoparticles are controlled release, protection of drug molecules, ability to combine therapy and imaging, specific targeting and many more.
- They have applications in drug delivery and diagnostics. The drug deliveries with polymeric nanoparticles are highly biodegradable and biocompatible.

Lipid-Based Nanoparticles:

- Lipid nanoparticles are generally spherical in shape with a diameter ranging from 10 to 100nm.
- It consists of a solid core made of lipid and a matrix containing soluble lipophilic molecules. The external core of these nanoparticles is stabilized by surfactants and emulsifiers.
- These nanoparticles have application in the biomedical field as a drug carrier and delivery and RNA release in cancer therapy.
- Thus, the field of nanotechnology is far from being saturated and it is, as the statistic says, sitting on the staircase of an exponential growth pattern. It is basically at the same stage as the information technology was in the 1960s and biotechnology in the year of 1980s.
- Thus it can easily be predicted that this field would witness a same exponential growth as the other two technological field witnessed earlier.

CLASSIFICATION O NANO-MATERIALS

NANO - MATERIALS

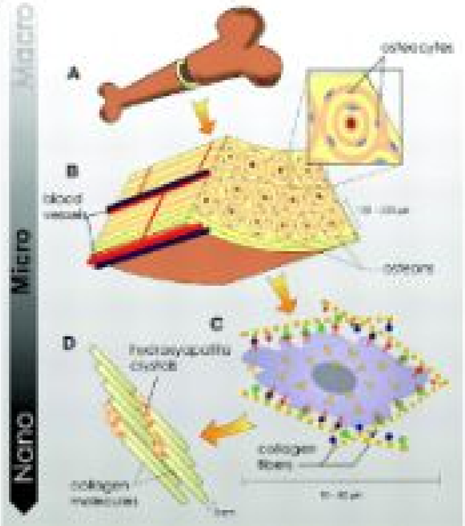
NATURAL NANO-MATERIALS

ARTIFICIAL NANO-MATERIALS

- Nanomaterials can be classified primarily into two types:
- Natural and artificially fabricated

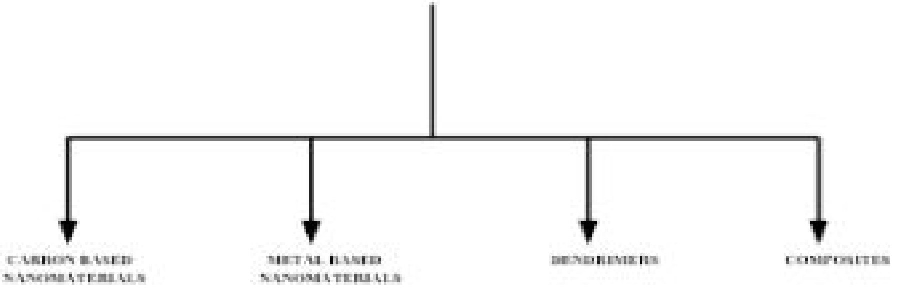
Natural nanomaterials:

- These include nanomaterials that exist in biological systems
- e.g. **viruses(capsid), substances in our bone matrix, ribosome machinery, ATPase etc**



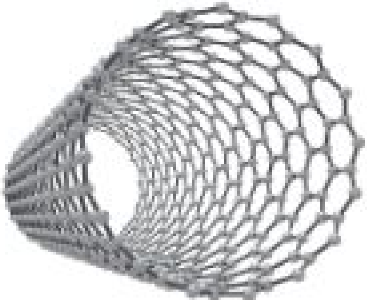
Artificial nanomaterials:

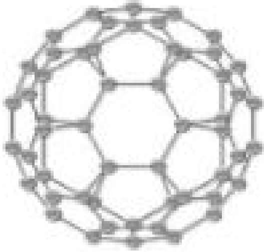
These are the ones that are fabricated by different experiments. They can further sub-divided into 4 classes:



CARBON BASED MATERIALS :

- These nanomaterials are composed mostly of carbon, most commonly taking the form of a **hollow spheres, ellipsoids, or tubes.**
- Spherical and ellipsoidal carbon nanomaterials are referred to as fullerenes, while cylindrical ones are called nanotubes.
- **These particles have many potential applications, including improved films and coatings, stronger and lighter materials, and applications in electronics.**
- USES : **This classification includes fullerenes, carbon nanotubes, graphene and the like.**





METAL BASED MATERIALS :

- These nanomaterials include quantum dots, nanogold, nanosilver and metal oxides, such as titanium dioxide.
- A quantum dot is a closely packed semiconductor crystal comprised of hundreds or thousands of atoms, and whose size is on the order of a few nanometers to a few hundred nanometers.
- Changing the size of quantum dots changes their optical properties.
- **Metal-based nanomaterials are materials made of metallic nanoparticles like gold, silver, metal oxides, etc. For example, titanium dioxide (TiO2) nanoparticles are extensively used in applications such as paint, sunscreen, and toothpaste.**

DENDRIMERS:

- These nanomaterials are nanosized polymers built from branched units. The surface of a dendrimer has numerous chain ends, which can be tailored to perform specific chemical functions.
- This property could also be useful for catalysis. Also, because three- dimensional dendrimers contain interior cavities into which other molecules could be placed, they may be useful for drug delivery.
- **Dendrimers are nanosized polymers built from branched units. They can be functionalized at the surface and can hide molecules in their cavities. A direct application of dendrimers is for drug delivery.**

NANOCOMPOSITE:

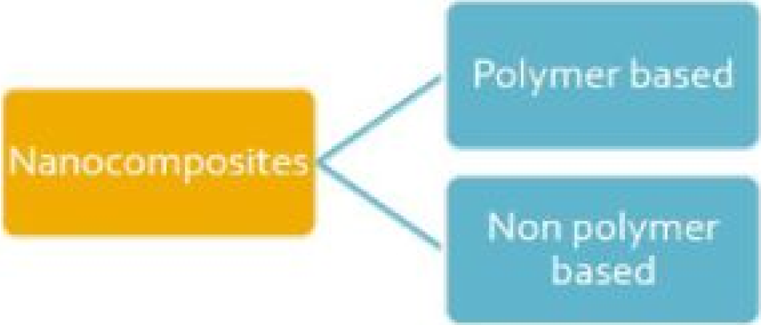
- A Nanocomposite is a composite material, in which one of the components has at least onedimension that is around 10-9 m.

OR

- A Nanocomposite is a multiphase solid material where one of the phases has one,two or three dimensions of less than 100 nm, or structure having nano-scale repeat distance between the different phases that make up the material.

- **Composite nanomaterials contain a mixture of simple nanoparticles or compounds such as nanosized clays within a bulk material. The nanoparticles give better physical, mechanical, and/or chemical properties to the initial bulk material.**

CLASSIFICATION OF NANO – COMPOSITES :



WHY POLYMER NANOCOMPOSITES ARE UNIQUE

- Increase in electrical break down strength of
- polymers.
- Melting temperature, color ,magnetization and charge capacity is more.

interacting Zone is increasing such that we can get our expected property.

Nanocomposites are upcoming materials which shows the great changes in all the industrial fields and it is also going to be a economical barrier for developing countries as a tool of Nanotechnology.

UNIQUE PROPERTIES:

- The unique properties of these various types of intentionally produced nanomaterials give them novel electrical, catalytic, magnetic, mechanical, thermal, or imaging features that are highly desirable for applications in commercial, medical, military, and environmental sectors.

- These materials may also find their way into more complex nanostructures and systems. As new uses for materials with these special properties are identified, the number of products containing such nanomaterials and their possible applications continues to grow.

NANOTECHNOLOGY AND WOOD PRODUCTS

- The wood industry in North America provides over 80% of all building materials used in residential construction. Wood-frame construction is very popular in the United States and Canada due to lower cost and ease of fabrication.
- Most importantly is the ability of forest wood (living and growing trees) to be impregnated on a molecular level with nanoscale composites. The latter could transform the properties of subsequently harvested trees and provide a new generation of wood composites with superior structural performance and durability.
- Nanotechnology offers the potential of reconstructing the cellulose fiber- to-fiber bonding and permitting fiber-to-plastic link at a microscopic level allowing the development of resin-free, light-weight wood-plastic composites with enhanced strength and serviceability .
- Other important contributions of Nano-science to wood relates to weathering and decay, fire protection, and performance monitoring.

- BASF has incorporated silica and alumina nanoparticles and hydrophobic polymers into the manufacturing of water repellent coatings that provide wood with superior, long-term weathering resistance. These are called nanodimensional barriers and could be applied in construction sites or integrated in the wood manufacturing process.
- Nano thin-film coatings would provide long- lasting finishing surfaces and render wood almost decay and weathering proof for decades.
- Wood is particularly susceptible to fire, a characteristic that makes it hazardous to use in assembly buildings.
- Recently developed nano-based potash provides superior adhesion qualities. When mixed into the resins used in binding the wood layers, nano- based potash adhesives allow the production of plywood and other dimensional lumber products with exceptionally high flash point and virtually fireproof.
- Nanoscale sensors(devices) incorporated in wood composite fibers could also provide feedback on product performance, environmental conditions, moisture content, insect and fungi activity, and overall structural performance. Such sensors are expected to become commercially available and affordable in the near future

NANOTECHNOLOGY AND CONCRETE AND PAVEMENT ENGINEERING

- Concrete is the most widely used man-made material, and the manufacture of cement accounts for 5 to 10 percent of all anthropogenic emissions of carbon dioxide.
- It is imperative to reduce concrete-related carbon-dioxide emissions as to combat global warming with two billion tons of cement being produced in the world every year.
- Researchers at MIT studied the nanostructure of cement, and proposed that through engineering cement on a nanoscale, it is possible to reduce carbon-dioxide emissions from cement production.
- Concrete has grown from the basic 4-ingredient compound (cement, water, sand, and gravel) to a much more complex structural system with

the addition of multiple chemical admixtures that impart specific qualities to the final product.

- Hydrated cement, which is the most active ingredient in the concrete mix, consists of thin layers of solid particles separated by pores that range from nanometers to millimeters.
- The porous structure of hydrated cement provides a pathway for various impurities and chemicals such as chloride salts to seep into concrete causing cracking and structural deterioration.
- Research has shown that replacing the silica, which is part of cement and conventional concrete mix, with nano-silica particles could substantially improve particle packing and reduce long-term degradation.
- Nanopowders have a remarkable surface area that could potentially permeate cement pores, which lead to considerable improvement in water and chemical resistance and therefore reduce concrete shrinkage and cracking.
- The performance of concrete could also be substantially improved by adding nanoengineered fibers and polymers to the mix in the field using acoustic energy to ensure homogenous distribution or under more controlled conditions during the manufacturing process of cement and other concrete components.

- Among new nano-based concrete additives are highly efficient super plasticizing polymers and high-strength fibers with exceptional energy- absorbing capacity.
- Recent nanotechnological advancements could lead to a new generation of concrete that is stronger, more durable and attractive as well smarter.
- One of the possibilities of nanomaterials with concrete is the development of sensors that act as part of the substrate, thereby providing feedback about internal stresses and early warnings of potential problems in concrete structures.
- Pavement engineers use a wide range of cement-based and concrete materials for the construction and maintenance of road pavement.
- Nano-based enhancement of concrete products would mean much stronger and durable road and highway surfaces and potentially better driving conditions due to reduced need for maintenance and road blocking.
- Bitumen-based products represent another major strand of materials used in road and highway pavement. The composite nature of hot-mix asphalt

(a mixture of aggregates and a bitumen binder) opens the door for significant improvements in material performance based on nanotechnology.

- Potential areas of improvement incorporate mechanical performance, durability, reflectivity and skid resistance, better binding, faster curing, and maintenance.
- Applications of Titanium Oxide nanoparticles on road surfaces promise to create a new generation of remarkable protective coatings for concrete and asphalt surfaces.
- The Titanium Oxide coatings capture and break down organic and inorganic air pollutants by a photo catalytic process. The result is environmentally friendly road surfaces with minimum long-term maintenance.

- The full potential of CNT"s may not be realized before crystallographic, stone waling, and other kinds of defects have been resolved.
- CNT polymer composites seem to provide a more practical application on the short-term especially as cement and concrete reinforcing fibers.
- However, adding Nanofibres to concrete requires the use of special sonic energy to break up the nanotube bundles and achieve even distribution of the nanofiber in the mix.
- The success of the application depends on improving the synthesis of fibers with the concrete mix.
- Another potential application of nanotube fibers is in the area of glass reinforcement. Nanofibers could substantially increase the strength of glass without comprising the transimissivity of glass panels.
- The production of longer CNT ropes could generally open the door for various structural applications such as suspension cables, long-span structures, and pre-and-post- tensioned concrete systems as well space frames and trusses.

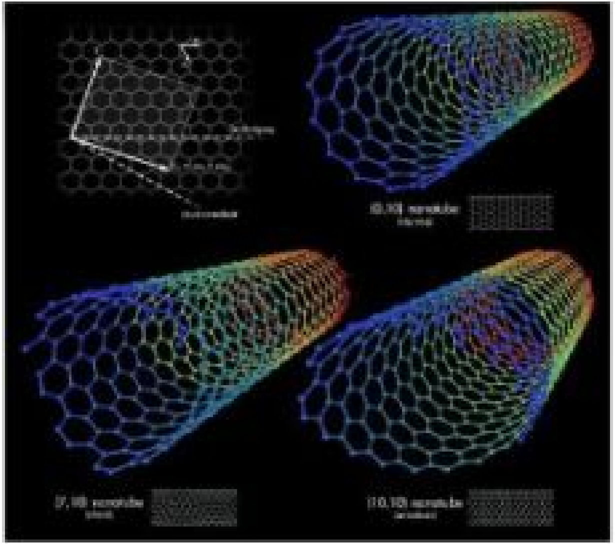


Figure 2. Diagram simulating single-wall CNT (Web-7)

CARBON NANOTUBES (CNT"S)

- CNT"s are nanoscale cylinders of carbon and come in single-or-multiple- wall structures.They are also referred to as „buckytubes" and endowed with superior structural performance that makes them the most perfect representation of nanotechnology with almost unlimited applications in materials, electronics, chemical processing, energy management.
- The carbon-carbon bond in the CNT results in superior strength and optimum performance up to their theoretical breaking limit. The Young"smodulus of elasticity of CNT"s exceed that of structural steel by several times.

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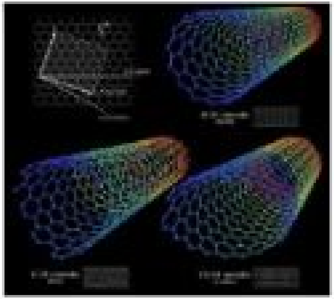
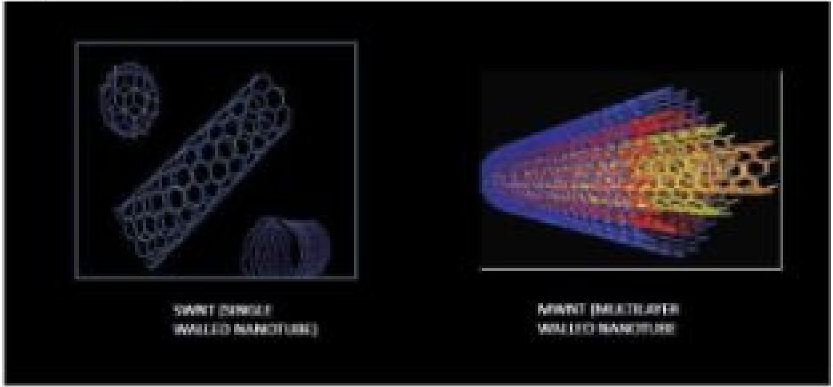
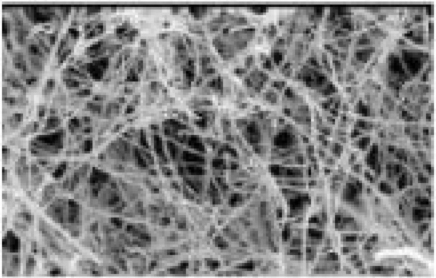


CARBON NANOTUBES :

- Tiny strips of graphite are rolled into tubes.
- Both single walled carbon nanotubes (SWNT) and multiwalled carbon nanotubes (MWNT) have been used for immobilization of protein/enzyme
- .MWNT have more dispersive properties.
- High electrical conductivity
- Mechanical strength
- Species can easily adsorb onto surface



- **CARBON NANOFIBRES**
- Enzymes can be immobilized inside or outside the fibre hence providing more surface area.
- Are defined as fibres with diametres less than 100nm .



APPLICATIONS-

- Skin cleansing
- skin therapy
- skin healing
- Filtration media
- liquid filtration
- gas filtration

WHY ARE NANOMATERIALS IMPORTANT?

- Have created a high interest in recent years by virtue of their unusual **mechanical, electrical, optical and magnetic** properties.
- Nanomaterial ceramics are of particular interest because they are more **ductile**(உடையாமல் கம்பிகளாக இழுக்கப்படும் ஆற்றல்) **at elevated temperatures as compared to the coarse grained ceramics.**
- **Polymer based composites with a high content of inorganic particles leading to a high dielectric constant are interesting materials for photonic band gap structure.**
- **Nanostructured metal oxide thin films are receiving a growing attention for the realization of gas sensors with enhanced sensitivity and selectivity.**

The use of nanomaterials in construction industry is restricted due to following reasons:

- The lack of knowledge concerning the suitable nanomaterials for construction and their behavior;
- The lack of specific standards for design and execution of the construction elements using nanomaterials;
- The reduced offer of nanoproducts;
- The lack of detailed information regarding the nanoproducts content;
- High costs;
- The unknowns of health risks associated with nanomaterials.

NANOMATERIALS FOR BUILDING CONSTRUCTION :

- Nanotechnology can generate products with many unique characteristics that can improve the current construction materials;
  - **lighter and stronger structural composites,**
  - **low maintenance coatings,**
  - **better cementitious materials,**
  - **lower thermal transfer rate of fire retardant and insulation,**
  - **better sound absorption of acoustic absorbers and better reflectivity of glass .**
- Because the size of the particles is a critical factor, the material properties significant differ at the nanoscale from that at larger scales.
- **Physical phenomena begin to occur differently below the boundary limit: gravity becomes unimportant electrostatic forces and quantum (மொத்தம்)effects start to prevail.**
- **At the same time, the proportion of atoms on the surface increases relative to those inside creating so-called "nano-effect".** All these nano-properties actually affect the materials behavior at macro-scale and, from this point, the power of nanotechnology is emphasized: if the elements are proper manipulated at the nanoscale, the macro- properties are affected and new materials and processes can be developed.
- Some of the important nanomaterials with potential use in construction industry are discussed here.

NANOTECHNOLOGIES FOR CONCRETE :

- **Concrete is a macro-material strongly influenced by its nano-properties. The addition of nano-silica (SiO2) to cement based materials can control the degradation of the calcium- silicatehydrate reaction caused by calcium leaching in water, blocking water penetration and leading to improvements in durability.**
- The addition of small amounts (1%) of carbon nanotubes can improve the mechanical properties of mixture samples of portland cement and water.
- Oxidized multi- walled nanotubes show the best improvements both in compressive strength and flexural strength compared to the reference samples.
- Addition of nanoscale materials into cement could improve its performance. Use of nano-SiO2 could significantly increase the compressive for concrete, containing large volume fly ash, at early age and improve pore size distribution by filling the pores between large fly ash and cement particles at nanoscale.
- The dispersion/slurry of amorphous nanosilicais used to improve segregation resistance for self-compacting concrete.
- It has also been reported that adding small amount of carbonnanotube (1%) by weight could increase both compressive and flexural strength.

NANOTECHNOLOGIES FOR STEEL :

- Steel is a **major construction material.**
- Its properties, such as **strength, corrosion resistance, and weld ability, are very important for the design and construction.**
- It is possible to develop **new, low carbon, high performance steel (HPS).**
- **The new steel was developed with higher corrosion-resistance and weld ability by incorporating copper nanoparticles from at the steel grain boundaries.**
- The addition of **copper nanoparticles** reduces the surface unevenness of steel which then limits the number of stress risers and hence fatigue cracking, leading to increased safety, less need for monitoring and more efficient materials use in construction subjected to fatigue issues .
- Vanadium and molybdenum nanoparticles improve the delayed fracture problems associated with high strength bolts, reducing the effects of hydrogen embrittlement and improving the steel micro-structure.
- The addition of nanoparticles of magnesium and calcium leads to an increase in weld toughness.

NANOTECHNOLOGIES FOR WOOD :

- Wood is composed of nanotubes or "nanofibrils".
- Lignocellulosic surfaces at the nanoscale could open new opportunities for such things as selfsterilizing surfaces, internal self-repair, Highly water repellent coatings incorporating silica and alumina nanoparticles and hydrophobic polymers are proper to be used for wood.

NANOTECHNOLOGIES FOR GLASS :

- The use of TiO2 nanoparticles to glasses leads to so-called self cleaning technology. Due to the nanoparticles photocatalytic reactions, the organic pollutants, volatile organic compounds and bacterial membranes are decomposed.
- As well, TiO2 being hydrophilic, his attraction to water forms drops which then wash off the dirt particles decomposed in the previous process. Fire- protective glass is obtained using fumed silica (SiO2) nanoparticles as a clear interlayer sandwiched between two glass panels which turns into a rigid and opaque fire shield when is heated.

NANOTECHNOLOGIES FOR COATINGS AND PAINTINGS:

- Nanotechnology is applied to paints in order to assure the corrosion protection under insulation since it is hydrophobic and repels water from the metal pipe and can also protect metal from salt water attack.
- Others applications refer to coatings that have self healing capabilities through a process of "selfassembly". In addition to the self-cleaning coatings mentioned above for glazing, the remarkable properties of TiO2 nanoparticles are put to use as a coating material on roadways in tests around the world .
- TiO2 is used to coat glazing because of its sterilizing and anti fouling properties.
- The TiO2 will break down and disintegrate organic dirt through powerful catalytic reaction. Furthermore, it is hydrophilic, which allow the water to spread evenly over the surface and wash away dirt previously broken down.
- Other special coatings also have been developed, such as anti-fraffiti, thermal control, energy sawing, anti-reflection coating.

NANOTECHNOLOGIES FOR THERMAL INSULATION :

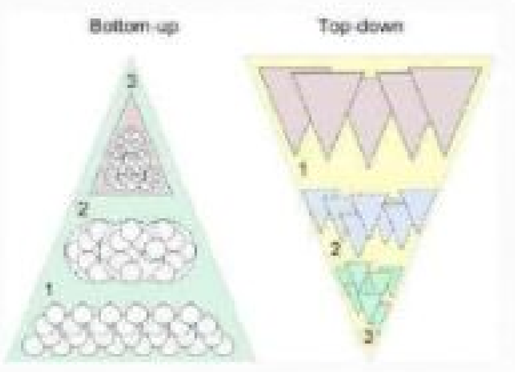
- Micro- and nanoporous aerogel materials are appropiate for being core materials of vacuum insulation panels but they are sensitive to moisture.
- As a possible remedy it was produced an ultra-thin wall insulation which uses a hydrophobic nanoporous aerogel structure.
- Another application of aerogels is silica based products for transparent insulation, which leads to the possibility of super- insulating windows.
- Micro or nano- electromechanical systems offer the possibility of monitoring and controlling the internal environment of buildings and this could lead to energy savings.

NANOTECHNOLOGIES FOR FIRE PROTECTION :

- Fire resistance of steel structures is often provided by a coating produced by a spray-on cementitious process.
- Nano-cement made of nanosized particles has the potential to create tough, durable, high temperature coatings.
- This is achieved by the mixing of carbon nanotubes with the cementious material to fabricate fibre composites that can inherit some of the outstanding properties of the nanotubes.
- This is achieved by the mixing of carbon nanotubes (CNT's) with the cementious material to fabricate fibre composites that can inherit some of the outstanding properties of the nanotubes such as strength.
- Polypropylene fibres are also considered as a method of increasing fire resistance and this is a cheaper option than conentional insulation.

NANOMATERIAL SYNTHESIS AND PROCESSING-

- Nanomaterials deal with very fine structures. This indeed allows to think of bottom up or the top down approaches.
- Bottom-Up approach :- Materials and devices are built from molecular atom which assemble themselves chemically by principles of molecular recognition.
- Top-Down approach :- Nano-objects are constructed from larger entities without atomic level control Eg – Sol Gel method

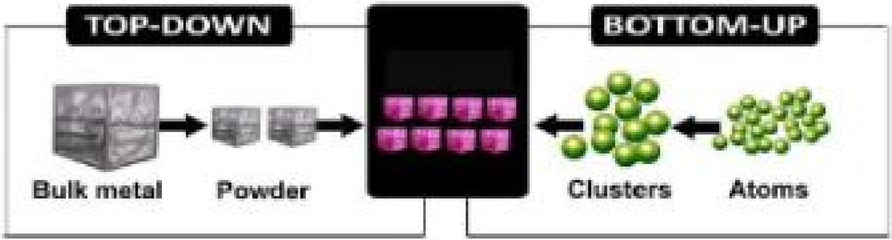


Top down Approach

- For nanomaterials synthesis, ball milling is used Macrocrystalline structures are broken down to nanocrystalline structures.

Bottom up Approach

- It is used to build from basic material, for example ,assembling materials fromatom/molecules
- The commonly used methods include sol-gel,hydrothermal, physical and chemical vapor deposition, epitaxial growth



FUTURE CHALLENGE :

- While nanotechology based construction products provide many advantages to the design and construction process, the production of these products, however, require a lot of energy.
- Also, the nano-tubes might cause a lung problem to construction workers. In other words, it creates an environmental challenge to the construction industry as well.
- Sustainability and environmental issues caused by growing economic development has gained intensive statewide and worldwide attention.
- Since the construction industry is heavily involved in the economic development and consumes great amount of resources and energy, its impact on environment is significant.

- Therefore, it is necessary and urgent to regulate the construction and its related performance to sustainable manners.
- The nanotechnology becomes a double-edge sword to the construction industry. More research and practice efforts are needed with smart design and planning, construction projects can be made sustainable and therefore save energy, reduce resource usage, and avoid damages to environment.
- It is necessary to establish a system to identify the environmentally friendly and sustainable of construction nanomaterials and to avoid the use of harmful materials in the future.

DISADVANTAGE :

- Loss of jobs (in manufacturing, farming, etc).
- Carbon Nanotubes could cause infection of lungs.
- It has very high initial investment costs along with high manufacturing costs.
- Atomic weapons could be more accessible and destructive.

Brainstorming Session

1.What is a nano – Particle ?/ Define a Nano – Particle?

2.What is a nano – Particle ? Define a Nano – Particle?


Information

NANOMATERIALS IN MEDICINE::

https://www.youtube.com/watch?v=aFU5Q
x-cLu8

CARBON NANOTUBES ::

https://www.youtube.com/watch?v=H-a2dC
9Bgak

CARBON NANOTUBES ::

https://www.youtube.com/watch?v=XbX-vr
koLJ0

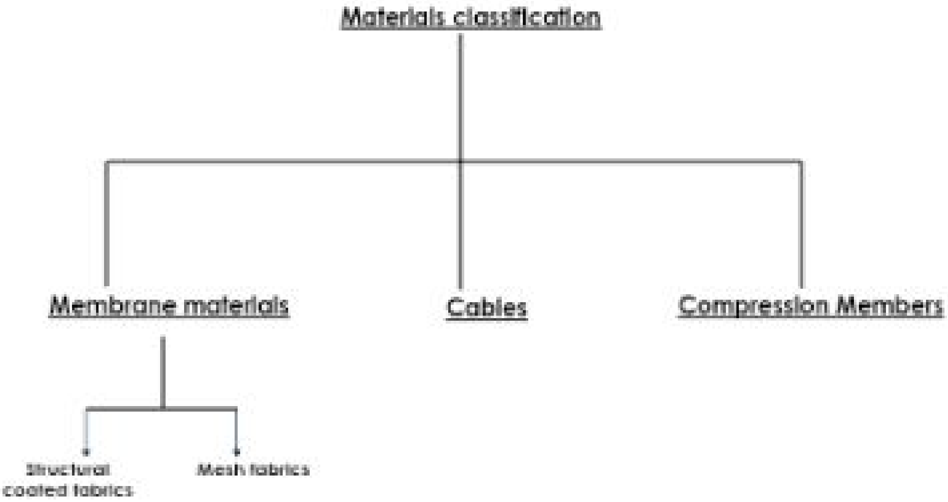
UNIT V

Types of materials and its constitution, manufacturing and construction technology requirement for 3D printed buildings structure and Extraterrestrial printed structures. Tensile fabric structure by digital printing. Translucent fabric, thin-film photovoltaics, texlon foil, PVC (poly vinyl chloride) coated polyester cloth and PTFE (poly tetra fluro ethlene) (teflon) coated glass cloth.

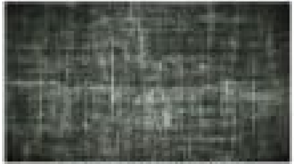
INTRODUCTION:

- A tensile structure is a **construction of elements carrying only tension**.
- The term tensile should not be confused (disordered) with tensegrity (பதற்றம்)
- Tensile structures are the most common type of thin shell structures.
- TENSILE STRUCTRES bring **style, curvature, translucency, and clear large spans to building scales.**

- Tensile structures have long been used in tents, where the guy ropes and tent poles provide pre-tension to the fabric and allow it to withstand loads.
- **The concept was mastered by German architect and engineer FREI OTTO, whose first use of the idea was in the construction of the WEST GERMAN PAVILION AT EXPO 67 in Montreal.**
- **Since the 1960s tensile structures have been promoted by designers and engineers.**

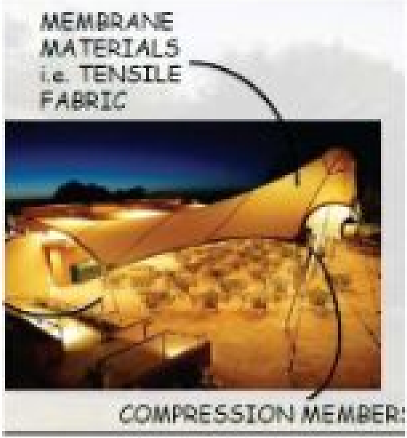

Materials classification
Membrane materials
Cables
Compression Members
Structural coated fabrics
Mesh fabrics

- Two main types of materials used are:
- MEMBRANE MATERIALS i.e. TENSILE FABRIC
- CABLES
- COMPRESSION MEMBERS.
- **The materials used are constantly being developed,** as sustainability and performance become more and more important.



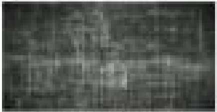
WOVEN COTTON AND CANVAS

TENSILE FABRIC



MEMBRANE MATERIALS :

- ***The biological based woven cotton and canvas , which we use to create the first fabric structures have been replaced by some of the most technical man made fabrics, to achieve permanent and lasting fabric architecture.***
- Modern coated fabrics have similar aesthetic properties, with some significant performance advantages, such as increased strength, cleaning, print ability, solar shading, acoustic characteristics.
- They also resist the absorption of moisture, resulting in much longer life spans.
- In general we use two generic types of coated fabrics:
- **STRUCTURAL COATED FABRICS**
- **MESH FABRICS**

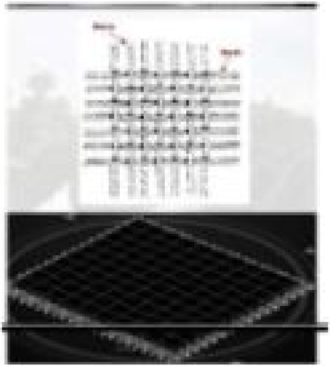


WOVEN COTTON AND CANVAS

TENSILE FABRIC

STRUCTURAL COATED FABRICS:

- A coated structural fabric consists of a **woven base cloth stabilized(become stable) and protected by a coating on both sides.**
- The base cloth consists of warp threads running the length of the roll and weft threads running across the width.
- The woven base cloth gives the structural strength while the coating gives **weather proofing, colour and other technical qualities.**

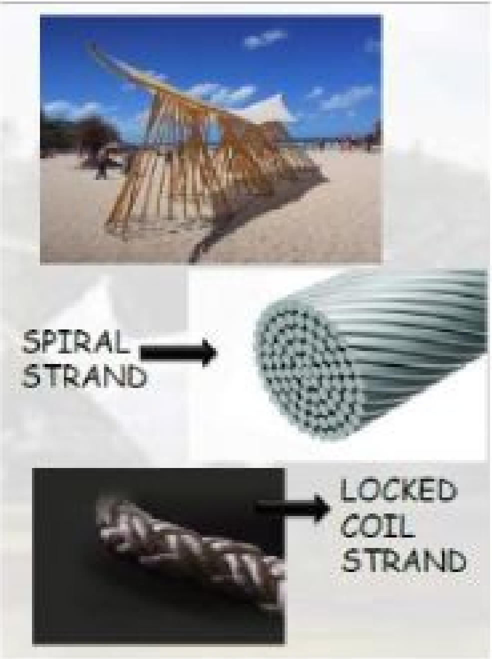


MESH FABRICS:

- A mesh fabric is a coated cloth with spacing between the thread bundles.
- With some meshes for interiors use the threads are coated before weaving.
- Due to openness factor of the mesh they are primarily used as shading and light diffusing device.

CABLES :

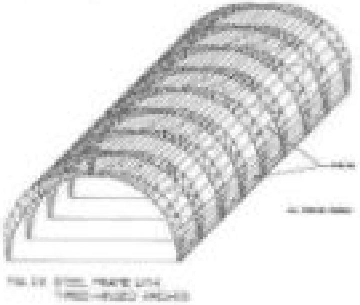
- Cables can be of mild steel, high strength steel (drawn carbon steel), stainless steel, polyester or bamboo.
- Structural cables are made of a series of small strands twisted or bound together to form a much larger cable.
- Steel cables are either spiral strand, where circular rods are twisted together and "glued" using a polymer, or locked coil strand, where individual interlocking steel strands form the cable (often with a spiral strand core).



Compression Members

COMPRESSION MEMBERS :

- Compression members are structural elements that are pushed together or carry a load, more technically they are subjected only to axial compressive forces.

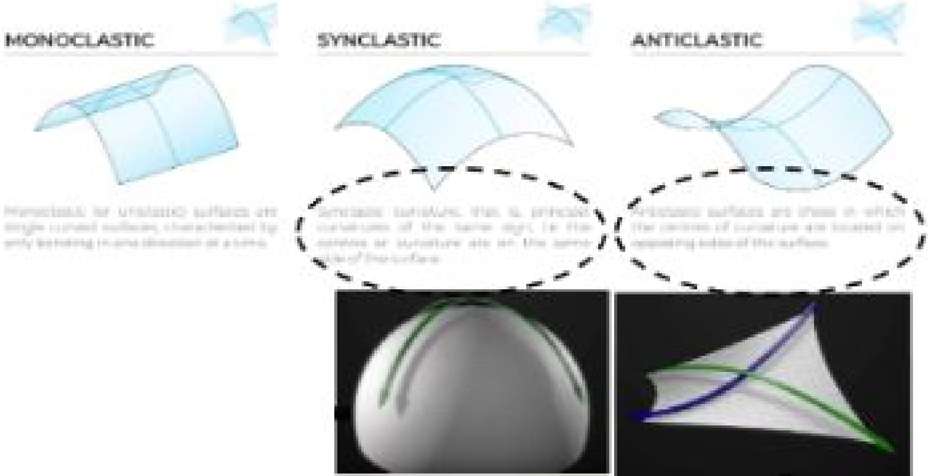


FORMS OF TENSILE STRUCTURES

FORMS :

While it is possible to have **flat tensile membrane, the key to strength & stability lies in the principle of double curvature.**

- There are in all two types of double curvatures:
- ANTICLASTIC CURVE
- SINCLASTIC CURVE

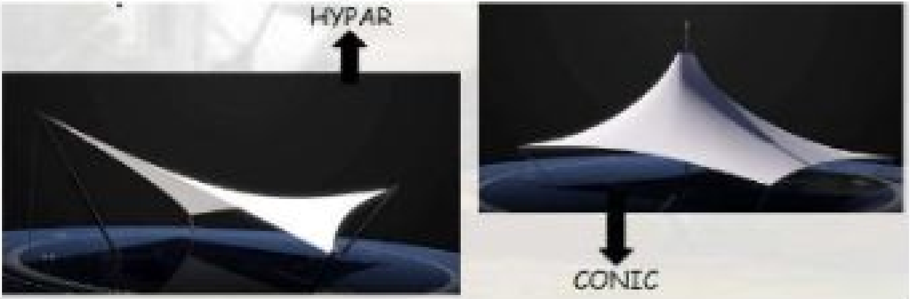


THE BASIC FORMS OF TENSILE ARCHITECTURE HYPAR

- **Traditional sail like form**
- **Theory of hypar often applied to other polygonal shapes**
- Complex undulating forms can be obtained with multiple high and low connection points.

CONIC

- Loads are spread horizontally around the full fabric form & vertically from apex to base.



BARREL SHAPPED VAULT :

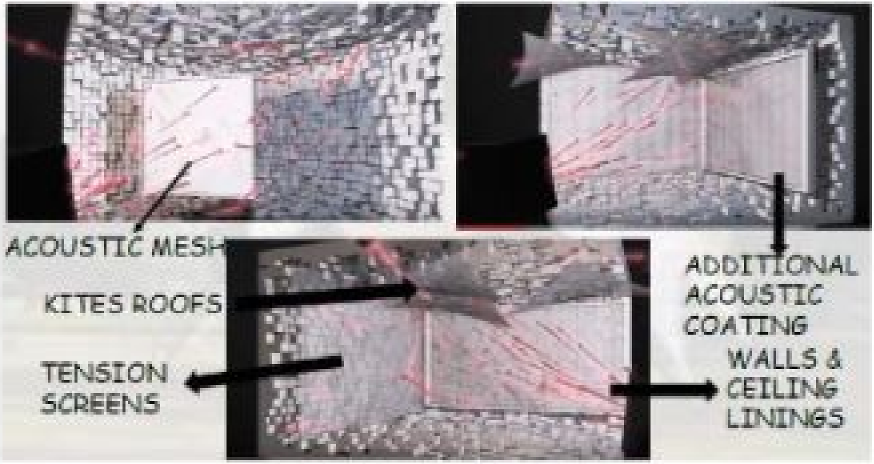
- **Although featuring double curvature** it can only be created with a steel, aluminium or timber structure tensioning the membrane placed to create the curve.

INFLATABLE :

- Adopts **sinclastic curve to create dimensionally stable shape .**
- Inflatable cushions are created where constant air pressure form the fabric into a shape
- Commonly used with a clear foil material called ETFE foil , PVC can also be used.

TEMPORARY INSTALLATIONS :

- Fabric panels are smaller to reduce storage & often the way we work with the loads has to be changed.
- Tensile structures are particularly situated for commercial schemes, where projects serves life of 20 to 30 years before it becomes outdated and requires redevelopment.



SOLAR CONTROL:

- Traditionally curtains & blinds are used to control light.
- We look for ways in which the light transmission can be controlled, diffused & reflected.
- Combining practical Application & aesthetic element is the key benefit.

INSULATION :


THERMAL MULTI-FOIL MEMBRANE
Multi Layer Membrane
TENSILE MEMBRANE
Nanogel
LIGHT
SOUND
Air Inflated Cushion

PRINTING :

- PRINTING CONSIDERATIONS
- color and size of the image
- lighting of the structure
- internal or external use
- print/fabric opacity
- required remount-ability
- fire rating

ENVIRONMENTAL

- **As most of the materials can recycled or reused, the environmental impact of TENSILE STRUCTURE is far less.**

PROCESS

- Designing a TENSILE STRUCTURE is as much an ART, as it is a SCIENCE.
- Throughout the designing process decisions are made on how the canopy will be constructed to meet the aesthetic, functional & engineering requirements.

ENGINEERING :

- Environmental loads like **wind loads, suctions, pressure, snow loads, snow drifts, they attack the fabric & the fabric withstands it.**

MANUFACTURE :

- It can be **entirely manufactured off site.**
- **Large clear span spaces are required for the fabrication of tensile structures,as the surface area of piece can reach hundred's of square metres.**
- Two processes are involved in customizing a whole piece of fabric viz. **CUTTING & JOINING.**

CUTTING : The large piece of fabric is first cut according to the requirement using machine

JOINING :

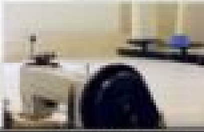
- WELDING
- Two pieces of fabric are mostly joined by WELDING them together.
- Some fabric are joined using RADIO
- FREQUENCY WELDING.
- Not all fabrics can be welded easily, and some require a bonding tape to ensure that they are welded properly.

RADIO FREQUENCY WELDING.

STITCHING :

- Stitching is done for small scale projects and for reinforcement in som patches of larger membrane.
- UV stable thread to join the material.

THREAD



INDUSTRIAL SEWING MACHIN

GLUEING :

- For some materials like silicone coated glass cloth, welding or sewing is not enough.
- A high bondage glue is used for joining in these cases.

INSTALLATION :

TENSILE STRUCTURE MATERIALS :

Structural Fabric

Structural fabric is the material that defines **lightweight** tensile structures.

Requirements

- As a primary structural element, **it must have the strength to span between supporting elements, carry snow and wind loads, and be safe to walk on.**
- **As enclosure element, it needs to be airtight, waterproof, fire resistant and durable.**
- **As daily use element, it requires to transmit daylight, reflect heat, control sound, and be easy to keep clean.**
- **Sample Materials**
- **Fiberglass, Polyester Cloth, PVC, Teflon.**

Polyester Tensile Roof

Teflon-coated Fiberglass Fabric

RIGID STRUCTURAL ELEMENTS

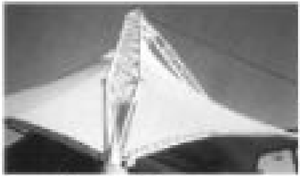
Rigid structural elements, such as **Masts, Struts and Arches**, are to support the **flexible fabric and cable membrane, generate its peaks, form its edges, and create the anchors that hold it down** .

Requirements

The rigid elements in tensile structures must be **strong, light, reliable, readily available, easy to fabricate, transport and erect.**

Sample Materials

Steel, Reinforced Concrete, Pre-stress Concrete, Laminated Wood, Aluminum, Composite Synthetic Materials.



Steel A-Frame

Concrete Piers

What Is an STL File?

The STL file format has become the Rapid Prototyping industry's defacto standard data transmission format, and is the format required to interact with Quickparts.

This format approximates the surfaces of a solid model with triangles. For a simple model such as the box shown in figure 4 (a), its surfaces can be approximated with twelve triangles, as shown in figure 4 (b). The more complex the surface, the more triangles produced, as shown in figure 4 (c). Figure 4: (a) (b) (c) The triangulation (or poly count) of a surface will cause faceting of the 3D model. The parameters used for outputting a STL will affect how much faceting occurs (Figures 4 (a) and Figure 4 (b)). You cannot build the model smoother than the STL file. If the STL is coarse and faceted the physical 3D printed model will be coarse and faceted as well. However, the smoother/ less faceted your surface is, (the higher the poly count or triangulation) the larger your file. 3D printing can only accept a certain file size; therefore, it is important to find a balance between your model, its desired surface, and the 3D printing process of your choice. STL means Stereo Lithography and can be exported into most CAD software suites, like Autodesk Fusion 360. For this reason, it has become the acronym" Standard Tessellation Language" .

The STL format only utilizes the three-dimensional description of the surface geometry without generating non-relevant information for printing like texture or color, leading to the popularity within the community . Each triangle, which represents the surface, is characterized by three vertices and the related unit normal .

Since a prototypical 3D model is closed, also called waterproofed, each vertex is part of three or even more triangles. These redundant vertices are memory expensive even when they are stored in ASCII representation. Most 3D printable models you can find on the internet are in the STL file format. The existence of this ecosystem, combined with STL-based software investments made by 3D printer manufacturers, has given rise to a large userbase that's heavily invested in the format

CABLE :

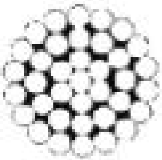
Cables serve a number of functions in tensile structure applications: reinforcement of the fabric where the spans and stresses get too large; linear tension support elements along ridges, valleys and edges; tie-backs and stays to stabilize rigid support element.

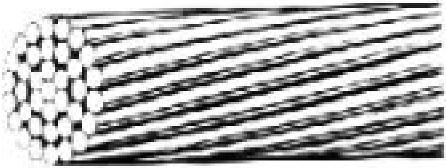
Requirements

The cables need to be light, high-strength and flexible to some extent.

Sample Materials

High Strength Bridge Strand, Steel, Kavlar Fiber, Glass Fiber.





WHAT IS A TENSILE FABRIC STRUCTURE?

- **Tensile fabric structures are characterised by the tensioning of a membrane system, typically with wire or cable. Using tension throughout structure provides the membrane with critical structural support.**
- Tensile architecture is the most common form of thin-shell structures.
- Tensile structures (otherwise known as tension structures) can hold many forms although it is generally based on two basic building designs: the Saddle and the Cone.
- This creates dramatic structural architecture and offers a variety of free form designs. The tensioning of the fabric eliminates and creases in the membrane and is strong enough to withstand any severe weather and potential damage.

WHEN TO USE A TENSILE FABRIC ?

- Tensile membranes can be used in a variety of situations. They use less material than traditional structures and as a result, weigh less and are easier to transport.
- They are flexible, robust and can be tailored to your exact requirements. As well as being practical, tensile fabric structures are a showpiece feature that offers an impressive local focal point.

WHERE TO USE A TENSILE FABRIC STRUCTURE?

- Tension structures can be used as a showpiece element that stands out against both traditional and modern buildings, urban focal point and local icons.

- Membrane canopies are ideal for wide column-free areas. The structures can span unsupported lengths of up to 150 feet and up to twice that amount with steel cable nets, and air structures can span thousands of feet withoutcolumns!

- Our tensile structures are great for temporary buildings, from schools and education centres or travelling exhibits.

- Need a prefab modular building? Our metal-framed tensioned structures are the most cost-effective modular frame buildings available.

- Tensile structures are brilliant, lightweight additions to existing buildings and can act as canopies, skylights, sheltered walkways, shaded areas or atrium roofing.

Tensile fabric structures are all prefabricated to engineered drawings and calculations, and applications include:

- Entrances
- Walkways
- Sports Stadiums
- Retail
- Exhibitions
- Landmarks

AN ANY SHAPE BE CREATED?

- As previously mentioned, tensile fabric structures are based on two basic building blocks of tensile structures. However, this is not to say that they are not versatile. The beauty of a tensile fabric structure is the ability to design and create them around your specific requirements.
- Every canopy uses the curves and principles of either the Saddle or the Cone, or combines elements of both. The Saddle is a hyperbolic paraboloid which means that it is a surface made by two high points and two low points. The geometry of the surface is orthogonal or made by the warping of a rectangular grid.
- The Cone is like a volcano shape using a radial geometry created by radians and hoops to create surfaces. These two forms can be combined to create an infinite number of permutations much like the circle and the square with classical architecture.

WHAT FABRICS ARE USED?

All fabrics will stretch when pulled in opposite directions to create tension however, some fabrics exhibit different characteristics. There are currently four types of fabrics that are used today for tensile fabric structures:

PVC Coated Polyester Fabric

- This is a cost-effective fabric having a 10 to 20-year lifespan. It has been used in numerous applications worldwide for over 40 years and it is easy to move for temporary building applications. PVC meets B.S 7837 for Fire Code.

PTFE Coated Glass Fabric (permanent structures only)

- This has a 30-year lifespan and is completely inert. It does not degrade under ultraviolet rays and is considered non-combustible by most building codes. PTFE meets B.S 476 Class 0 for Fire Code.

ETFE Foils (permanent structures only)

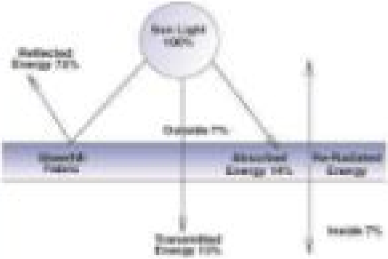
- This is used in inflated pillow structures where thermal properties are important. The foil can be transparent or fritted much like laminated glass products to allow any level of translucency.

PVC Glass Fabrics

- This material is used for internal tensile sails, such as features in atriums, glare control systems, with a minimal need for maintenance. PVC glass fabrics meet B.S 476 Class 0 for Fire Code.

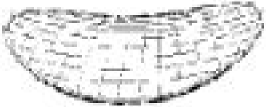
ARE TENSILE STRUCTURES ENVIRONMENTALLY SUSTAINABLE?

- **Tensile structures generally use light coloured roofs to reduce the heat that is attracted.** They use very small amounts of material for large spans: they allow for natural ventilation using the **Venturi effect (Venturi Effect** The **Venturi Effect** is utilized in **buildings** for natural ventilation. ... The purposeful creation of positive and negative air pressure zones can create an increased air flow through a building or across a surface creating a cooling **effect)** and **they provide translucency for natural daylighting**. PVC polyester, expanded PTFE, polyolefin fabrics and ETFE foils can be recycled by the supplier for lower grade applications.



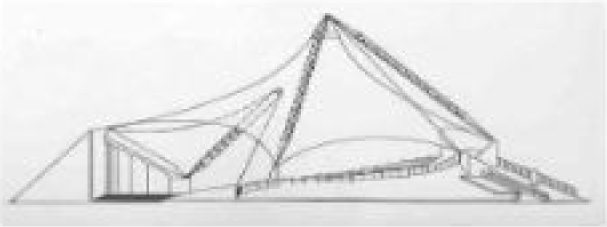
TYPES OF FABRIC STRUCTURES

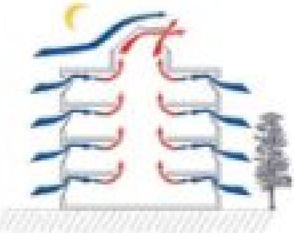
- Saddle roof
- Mast supported
- Arch supported
- Combinations



Saddle roof :

- Four or more point system when the fabric is
- stretched between a set of alternating high and low points





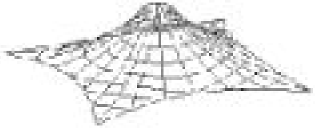
Mast supported :

- Tent-like in appearance, mast supported structures typically have one or sometimes several peaks that are supported by either interior or perimeter masts.
- The fabric is attached to the interior mast by special connections, usually a bale ring or cable loop.

- **Mast-supported structures can also be supported by adjacent buildings. The peaks of a mast supported structure are determined by the design and how the fabric is attached.**

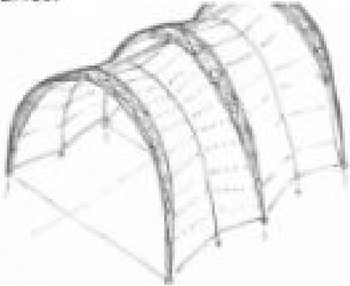
- Openings are typically ovoid or elliptical. The fabric that extends from the top of the opening is seamed and can necessitate patterning.

- Mast supported systems are suitable for long span roofs.

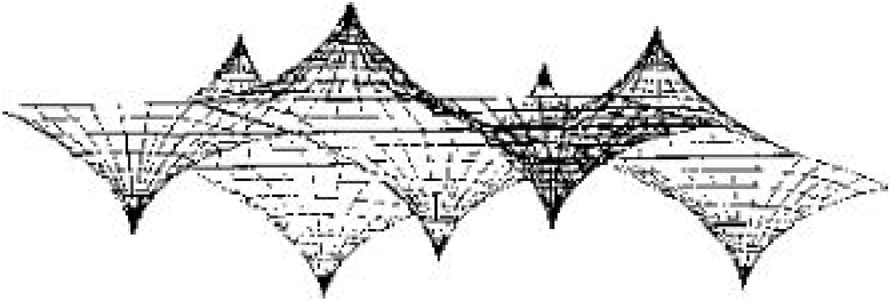


Arch supported

- Curved compression members are used as the main supporting elements and cross arches are used for lateral stability.
- In a plane arch, large differences between the thrust lines and the main geometry will produce large bending moments that in turn produce large changes in shape and high stresses in the arch chord section.
- One method to significantly reduce these effects is to tie or restrain points along the arch chord to reduce the initial large deformations of the chord
- The buckling length of the arch chord can also be reduced by discretely or continuously supporting the chord with tension elements or systems comprised of cables or membranes.



- Combination
- Combination of several support types.
-



ADVANTAGE :

- Longer life cycles of materials.
- Materials can be re-used in form.
- Most materials are completely recyclable.
- Less impact on site.
- Less construction debris after demolition.
- Unique designs
- Lightweight and flexible
- Environmentally sensitive
- High strength weight ratio

DISADVANTAGE

- Little to no rigidity
- Loss of tension is dangerous for stability
- Thermal values limit use

GRANSTAND TENSILE MEMBRANE STRUCTURES

- Designs and builds grandstand structures for a variety of sporting and event facilities to provide shade or shelter from weather conditions such as sun, hail, snow, and rain.
- FabriTec has built grandstands for many sporting events uses including baseball, football, soccer, swimming, and tennis. FabriTec tensile structures are in use by collegiate, professional, and Olympic level venues around the world.
- Built in half the time and at around half the cost of a conventional building, precision-crafted tensile membrane structures give architects, engineers, and developers a great alternative to conventional construction. There are shapes, forms, and surfaces that can be created with a lightweight fabric architecture that cannot be replicated with any other method of construction.
- Tensile grandstands are low maintenance, provide abundant natural light, and are sustainable.

Materials

-Membrane
- ETFE foil
- PTFE
- PVC fabrics

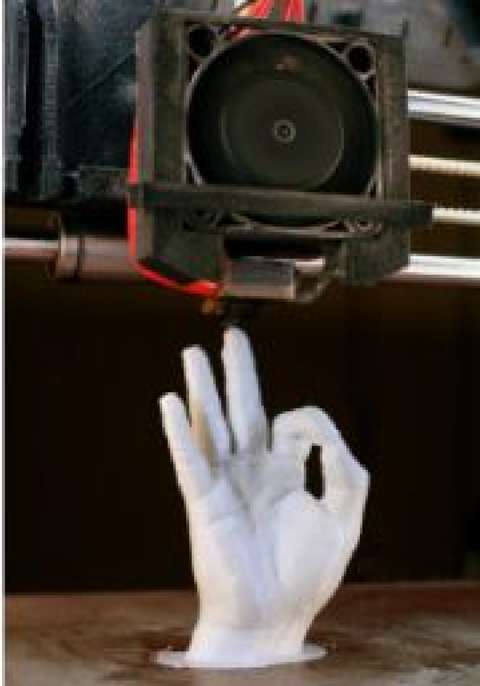
-Support structures, cables, fittings
- Cold-formed carbon steel

3D PRINTING TECHNOLOGY

INTRODUCTION :

- **Printing with a three-dimentional (3D) printer; is the process of converting objects modeled in the computerized environment into real objects in layers using the required raw materials.** The 3D printer, seen as a complex and expensive technology in the years it was invented.

- However, it has been one of the most important facts of the industry over the years. **Since 1983, the date Charles W. invented 3D printer, the new technology shows rapid developments and entered into every field of various industry**, such as automotive, aerospace and space technology and medicine, today .



- **Tissue engineering and regenerative development** have made it possible to print such organs or tissues with the **help of bio-printers produced by 3D printing technology.**

- These achievements attract the attention of different industries and science fields about 3D printing technology. The 3D printing version of the concrete is currently being studied in the construction industry applications and academia .

What is 3D Printing?

- **3D printing or additive manufacturing is a process of making three dimensional solid objects from a digital file.**
- **The creation of a 3D printed object is achieved using additive processes.** In an additive process an object is created by laying down successive layers of material until the object is created. Each of these layers can be seen as a thinly sliced cross-section of the object.
- *3D printing is the opposite of subtractive manufacturing which is cutting out / hollowing out a piece of metal or plastic with for instance a milling machine.*
- ***3D printing enables you to produce complex shapes using less material than traditional manufacturing methods.***

- Today, with advances in technology, it is possible to print engineering structures with a 3D printer .
- **3D printing has become an innovative and promising method, with an increase in use for cementitious material.**
- The use of this printing technique in waste materials and recyclable materials is under investigation .

[illegible]

- **Nasa reveals that —we will not be able to get everything we need from our world for the habitats that will be created on the surface of the mars and moon, and even beyond, and the explorers who will go there.-**
- Because it is impossible to take all these conventional resources from our world, we are competing for technological ideas and innovative inventions to create structures that will enable the establishment of habitats that can be lived with 3D printers in places where we are going
- **Nasa also has intensive activities in 3D concrete printing works .**
- In global and regional terms all countries and research groups that are effective in construction industry should change their focus on revolutionary innovations and technological developments for determination and management of models and methods to investigate and additional studies on 3D printing.

(a)C-Fab Wall Partitions

(b)3D concrete printed storm drain

(B)WASP 3D Shelter

Winsun: 3D Printed House (2013) – 3D Printed Office (2016)

- In 2013 a Shanghai based company called Winsun produced 10 small full- size prefabricated homes in just one day.

- The material that is extruded from the printer's nozzle is a trademarked mixture consisting of concrete, cement, glass fiber reinforced gypsum, and fiber reinforced plastics bonded together with a proprietary additive that enables the concrete to fully cure within a couple of days (depending on compressive strength). 50% of this material is sourced from recycled construction waste.

- The key to this mixture is finding a balance between flow-ability and build- ability so that the concrete can support itself without the need for formwork, while also maintaining a sufficient compressive strength. Although Winsun does not release their specific design.

- It must be noted that these homes are not entirely printed on site, but rather prefabricated in a factory and shipped on site where the walls are placed onto pre poured slab foundations and reinforced with traditional steel reinforcement.
- Additionally, the roof, doors, and windows are not printed using 3DP technology. Each wall is printed in a hollow fashion with an internal diagonal zig-zagging reinforcement system .
- This allows for the architects to implement calculated paths for insulation, plumbing, and electrical within their computer aided designs .
- Three years later, Winsun used the same printer and material to produce the worlds' first 3DP office building for the United Arab Emirates National Committee as their headquarters for the Dubai Future Foundation (DFF).
- This 2,700 square foot building was also printed offsite in a factory, cut in half for shipping purposes, and assembled onsite. The entire crew consisted of 18 laborers, including one printer operator, seven laborers for assembly, and ten laborers for mechanical and electrical .
- The total project duration from beginning of printing to finished assembly took only 17 days for a total of $140,000 in construction and labor costs .
- Time, Cost, and Materials Savings

1.) Time Savings: Winsun's 3DP technique for the construction of both the 10 houses and office building in Dubai were reported to have, on average, a 30% schedule reduction than that of similar buildings using traditional construction methods (futureofconstruction.org, 2016).

2.) Cost Savings: Compared to traditional on-site construction methods, Winsun was able to save about 80% on construction and labor costs

3.) Materials Savings: The accuracy and precision of Winsun's 3D concrete printer results in 30-60% less material waste as compared to traditional concrete placing (depending on size of printed components). This reduction in waste accounts for absence of formwork since Winsun's fast- curing concrete mixture is able to support itself while being extruded layer upon layer. Additionally, 50% of the concrete material used has been sourced from construction waste

(a)Internal Reinforcement

(b)3DP House

(a)3DP Office

ADVANTAGES OF 3DP

- 3DP technology offers many advantages to the construction industry. The four main areas where 3DP can have the most significant effects are in labor efficiency, time and cost savings, environmental/economic impacts, and design complexity.

LIMITATIONS OF 3DP

- Although the potential advantages of 3DP seem promising, the existing state of the technology possesses many limiting factors that impair its growth in the construction industry.
- The first and most obvious limitation is the sheer size of the printers.
- Material is next largest limiting factor. As it exists today, construction grade 3DP technology is only compatible with various concrete mixtures, and plastics. Such concrete mixtures range from lightweight air-entrained concrete, to eco-friendly concrete mixtures that utilize construction waste, to structural concrete.
- There is also high reluctance from general contracting companies to invest in 3DP technology.
- Building codes and regulations also pose as a large barrier for 3D printing in construction. Most building codes and procurement standards make no mention of 3DP technology therefore making it difficult to legally implement 3DP components onto large scale projects.

How 3D Printing Has Transformed the Construction Industry ?

Reduced Injury

Reduced Material Costs

Quicker Construction

New Markets

Cheaper Construction

Improved Form

Process of 3D Printing of Buildings Construction by BIM in Figure 3. A model is prepared in a 3D modeling application.

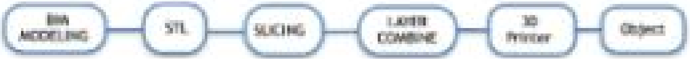


Figure 3. 3D Printing Process

- **BIM (Building Information Modeling) BIM** is a digital representation of physical and functional characteristics of a facility creating a shared knowledge resource for information about it forming a reliable basis for decisions during its life cycle, from earliest conception to demolition.

- (RIBA and CPIC) "a coordinated set of processes, supported by technology that adds value through creating, managing and sharing the properties of an asset throughout its lifecycle.

- An innovative and collaborative way of working that is underpinned by digital technologies which support more efficient methods of designing, creating and maintaining the built environment .

- The construction industry has been facing a paradigm shift to (i) increase: productivity, efficiency, infrastructure value, quality and sustainability, (ii) reduce: lifecycle costs, lead times and duplications, via effective collaboration and communication of stakeholders in construction projects .

- Building Information Modeling (BIM) seeks to integrate processes throughout the entire lifecycle .

- If used appropriately, BIM can facilitate a more integrated design and construction process and generate substantial benefits. For instance, fewer design coordination errors, more energy efficient design solutions, faster cost estimation, reduced production cycle times and lower.

- BIM introduces a new work paradigm offering powerful perspectives for the integration and coordination of different domains and the processes involved in the design, construction and operation of buildings. The base schema for the BIM data is Industry Foundation Classes, an international standard for the exchange of BIM data, which provides a generic data schema covering among others architectural, building service and structural elements.

- Building Information Modeling is an integrated process designed to generate and manage building data from design through construction. This process can also be used in building life cycle, maintenance, operations and cost analysis. The BIM process utilizes 3D software for increased project coordination and communication with multiple trades to provide a better end-product for the user .
- It might be tempting to write 3D Building Information Modeling (BIM) off as a little more than 3D animation, 3D design, or 3D CAD. But unlike some other model-based processes, BIM has the promising potential to guide businesses by evaluation through every step of the construction process and even after construction is complete. According to the US.
- National Building Information Model Standard Project Committee, BIM is a "digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition."

- 706 Mehmet Sakin et al. / Energy Procedia 134 (2017) 702–711 Author name / Energy Procedia 00 (2017) 000–000 5 BIM, meanwhile, is at the heart of the 3D printed building movement providing the software to govern the design and construction process.
- Austrian architect, Wolf D Prix, is pioneering the use of robots at one of his latest projects the Museum of Contemporary Art and Planning Exhibition (MOCAPE) in Shenzhen, China.
- Led by a BIM system, robots will mound and assemble, weld and polish the hyperbolic metal plates that make up the museum's irregularly curved stainless-steel center. Combining robots with the use of 3D-printed building components will make it much easier to create buildings with complex shapes, Prix said.
- It is quicker too he points out. "Normally this part of the building would take eight months with 160 workers on the site," said Prix. "Now we need eight workers on site, and it takes 12 weeks." With quicker construction, less labor, lower cost, as well as greater control and customization to create a leaner, greener, smarter building it's fair to say that the invention of 3D printed buildings, as Schmidt suggested, has made it easy to predict the future of construction.
- Surprisingly, the construction industry has not changed much in the last 100 years. There are new things happening in mega-construction projects; larger skyscrapers, longer bridges and other huge structures; but not in day-to-day construction; that's pretty much stayed the same.

- Other than a few innovative materials and techniques, along with a greater reliance on power tools, home building is pretty much the same today, as it was 100 years ago. This might all be changing soon. 3D printing, which has been the realm of engineering test labs, may make a drastic change in the ways that our building structures are built.
- In recent years, 3D printers have moved out of the engineering laboratory, where they've been hidden for over 20 years, and are beginning to be used for other things. Artists have discovered this new medium, and yes, it's being looked at for construction as well .
- Process of 3D Printing of Buildings Construction by BIM in Figure 3. A model is prepared in a 3D modeling application.

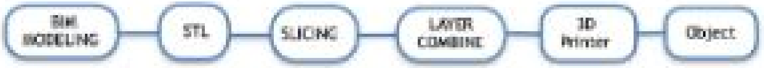


Figure 3: 3D Printing Process

LIMITATIONS OF 3D PRINTING IN CONSTRUCTION

There are certain problems with current 3d printing technologies which must be addressed during and before wide spread adoption of the technology.

1) **Foundations:** *3d Printing is not ideal for in-situ casting of foundations and will require either the gantry system to be disassembled prior to backfilling for the plinth or will require the foundations to be constructed by precast elements or by conventional technologies.*

2) **Shear and Seismic Strength:** Printed elements have weaker shear strength along the boundaries between two adjacent layers and elements such as columns become vulnerable to failure along those axes. The structures have also not been evaluated for their response to seismic loads and methods for including reinforcements are not well explored.

3) **Spans:** To print large spans in-situ printers either need temporary supports or the elements need to be printed off site and then moved into place. This adds a step into the process and required some additional equipment and manpower. Alternatively, curved shapes can be used to give larger spans and better support systems.

4) **Implications to labour market:** After Agriculture, Construction is the industry which contribute the most to the labour market of India. Adoption of this technology would significantly impact manpower requirements, which would lead to a significant rise in unemployment among the classes typically involved as labourers and workers on site. The increase in mechanisation would impact the overall state of the economy in unpredictable ways, especially when seen in the context of increasing mechanisation in other similar fields such as transportation and manufacturing. However, it will also lead to skilled, green and dignified jobs, offering better work environments.

5) **Lack of Standards:** Currently 3D printing has only limited standardisation worldwide. While the industry is still developing standards for consumer grade plastic printers, several organisations are developing construction printers of various scales. Standardisation in IS and ASTM codes will become very important within the next decade.

6) **Intellectual Property Rights:** Many of the technologies being developed right now are currently under patent, with most scheduled to expire around 2030. As these technologies cross over into the public domain, the market shall evolve rapidly to incorporate these into all kinds of construction applications.

TRANSLUCENT FABRIC

- Otherwise known as semi – opaque, this group of fabrics consists of materials that are woven in a solid form and material with an open weave which includes holes and patterns.
- Fishnet fashion fabric, lace and even hessian could be considered semi opaque, simply because there are some parts you can see through and some you can't. The group which is more considered translucent consists of fabric with a complete weave that has semi see through visibility
- This fabric ranges in translucency. Some you can see slightly through when the fabric is flat and some show a lot more translucency when held up to light or over objects. The images below demonstrate this change depending on light and where the fabric is placed.
- As you can see with the metallic lame fabric here, when laid flat it appears opaque and you can't see through to the text. Yet when the fabric is raised even slightly it becomes very obvious the fabric is in fact translucent. So even though the fabric is opaque, when flat it certainly doesn't belong in the opaque category.

TEXLON FOIL

1. Foiltec designs, engineers and manufactures Texlon Foil Systems, intelligent dynamic systems which are capable of adjusting their shading, thermal and aesthetic characteristics in response to specific programmatic and climatic requirements.
2. Texlon is a cladding and roofing system consisting of two or more layers of ETFE film welded into panels and anchored to an aluminium perimeter frame which can be attached to a support structure. Whereas in inflated buildings the load is borne by compressed air, the air supplied to the Texlon system plays a secondary role.
3. Although air is important for insulation, Texlon transparent roof systems do not require air to maintain their structural integrity.

MATERIAL PROPERTIES

SENSORIAL

GLOSSINESS	GLOSSY
TRANSLUCENCY	[illegible]
STRUCTURE	OPEN
TEXTURE	SMOOTH
HARDNESS	[illegible]
TEMPERATURE	MEDIUM
ACOUSTICS	[illegible]
ODOUR	NONE

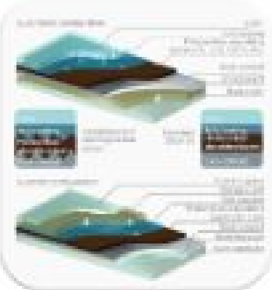
TECHNICAL

FIRE RESISTANCE	GOOD
UV RESISTANCE	GOOD
WEATHER RESISTANCE	GOOD
SCRATCH RESISTANCE	GOOD
WEIGHT	LOW
CHEMICAL RESISTANCE	GOOD
RENEWABLE	NO

THIN FILM PHOTOVOLTAICS

Characteristics of thin film photovoltaics

- Thin film photovoltaic modules produce power at low cost per watt. They are ideal for large scale solar farms as well as Building Integrated Photovoltaic applications (BIPV). They benefit from generating consistent power, not only at elevated temperatures, but also on cloudy, overcast days and at low sun angles.
- thin film photovoltaics can offer excellent aesthetics. Thin film photovoltaic modules also benefit from a relatively small drop in power output under partial shadowing when compared with crystalline silicon photovoltaics.
- This gives thin film photovoltaic modules greater design flexibility when integrated into the building envelope.
- Thin film photovoltaics consist of a stack of extremely thin photosensitive layers sandwiched between a top Transparent Conductive Oxide (TCO) coating and a back contact. The photovoltaic layers are laminated between a TCO glass such as NSG TEC™, and a low cost backing material, such as standard or thermallstrengthened Pilkington **Optifloat**™ Clear glass.

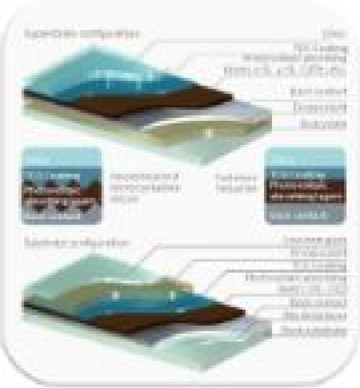


Thin Film photovoltaic technologies

NSG TEC™ can be used with a number of thin film photovoltaic technologies, including amorphous silicon (a-Si), tandem (a-Si/μ-Si) – a combination of amorphous and microcrystalline silicon, cadmium telluride (CdTe), copper indium (gallium) diselenide (CIS, CIGS) and dye-sensitised solar cells (DSSC).

1. Pilkington Optiwhite™ range of products may also be used as a base for TCO deposition, or as a top cover plate for CIS and CIGS thin film photovoltaics. Pilkington **Optiwhite™** is a range of ultra- clear float low iron glass, which maximises the solar energy

transmittance and, therefore, the efficiency of the photovoltaic modules.



PTFE (POLY TETRA FLURO ETHLENE) (TEFLON) COATED GLASS CLOTH:

- Are fabrics woven from continuous filament glass yarns and coated with polytetrafluoroethylene (PTFE) to give a stiff, flexible, fairly smooth surfaced material that is chemically inert with excellent release properties.

- Polytetrafluoroethylene (PTFE) is a fully fluorinated polymer which is semi-crystalline, semi-opaque, and white. It has exceptional chemical resistance being unaffected by nearly all chemicals and also has a very high oxygen index (i.e. is fundamentally non-flam).

- It has a very low coefficient of friction and is stable in high temperatures. It is soft, easily deformed, highly susceptible to creep, and low in strength with poor radiation resistance.

- It is relatively expensive and cannot be melt-processed (even though in theory it melts at 327 °C, the melt viscosity of normal grades is virtually infinite) and so is formed by powder sintering metods.

APPLICATIONS:

- Industrial applications of Polytetrafluoroethylene coated glass fabric [PTFE 75/ Glass 25] include release material, protective curtains and conveyor belts e.g. in food processing machines, seals, high temperature electrical insulation, O-rings, bearings, non-stick coatings and linings for vessels etc.
- Its rare properties make it valuable for numerous laboratory applications.
- PTFE Adhesive Glass Cloth (with protect yellow paper) is well known as its smooth surface, non stick, chemical resistance and high temperature resistance and insulation prosperities.
- It is widely used in packaging, heat molding, laminating, sealing and electrical industries etc.,
- PTFE adhesive fabric is enhanced by fiberglass fabric, which improved its tensile strength. It could be used in plastic molding except additional applications, it is easy to install . And we can cut the size according to the customer requirements.
- Width is 1000 mm and in continuous length.
- Glass cloth contribute excellent strength and dimensional stability, exhibit essentially zero flow under heat and pressure and are highly resistant to cut-through. Also in tape and belt form.

PROPERTIES:

- Top side provide good characteristics of PTFE, such as electrical characteristics, heat resistance, chemical resistance, low friction coefficient and non-adhesiveness.
- Flame resistance Made by insulating material.
- Can smoothly adhere, wind, band, and seal.

PVC

- Polyvinyl chloride (PVC) coated polyester, is the most commonly selected material for tensile membrane structures. PVC is chosen for its excellent strength, water proof properties, flexibility, transparency, and durability.
- It is the most cost-effective and versatile tensile fabric, and meets a large range of colour and application needs, both permanent and temporary. PVC is treated to be stain, fire and UV resistant.

Life span

- The approximate design life of PVC coasted polyester fabric is 15-30 years, depending on grade of PVC selected, location, and exposure to environmental pollution. PVC fabric warranties can range anywhere from 5 to 15 years, depending on the supplier and application.

Solar Transmission

- PVC fabric reflects around 89% of solar energy, allowing 9% visible transmission through the fabric. The rate of transmission is dependent on the colour of the fabric, coatings, printings and environment. These coatings can contain anti-fungicides.
- Therefore, the stronger the self-cleaning properties of the fabric, the less light transmission is interrupted by dirt adherence and aging of the fabric.

Applications

- PVC polyester is used on structures all over the world and in every environment. Applications include: covered walkways, car park structures, entrance features, outdoor classrooms, play areas, sport court enclosures, swimming pool enclosures, and event spaces.
- PVC is a strong fabric that can be folded, making it ideal for retractable and temporary structures such as tents, warehouses, remediation, and mining structures, which need to be demounted and stored often.
- With the ability to print on the fabric with ease, PVC is often used in projects where branding is important.

Sound Absorption

- PVC can be altered to manipulate the sound absorption rate of the structure. Various coatings can be applied to PVC dependent on the requirements of the structure.
- For example, an indoor aquatic centre will use PVC that has been specifically treated to absorb as much sound as possible, while a small room or area will benefit from strong acoustic retention.

Common uses for PVC polyester:

- Transportation: truck tarps/covers/side walls.
- Construction: Oil booms, tarps, commercial sewing.
- Amusement/recreation: tents/awnings, inflatables, pool covers, boat/pontoon/ATV covers.
- Athletics: Gym and athletic mats, wall padding. Loading dock and door: roll-up doors, dock seals, industrial curtains.
- Food service and restaurants: equipment covers, patio enclosures

Brainstorming Session

1.What is a nano – Particle ?/ Define a Nano – Particle?

2.What is a nano – Particle ? Define a Nano – Particle?


Information

3D PRINTING:

https://www.youtube.com/watch?v=[illegible]

FREI OTTO – GERMAN PAVILLION:

[illegible]

3D PRINTING:

http://www.youtube.com/watch?v=[illegible]

3D PRINTING PROCESS:

[illegible]

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