

Structures in Nature



STRUCTURES IN NATURE

DESIGN RESEARCH SEMINAR

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GUIDE
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Declaration

The content produced in the project report is an original piece of work and takes due acknowledgement of referred content, wherever applicable. I also declare that I adhered to all principles academic honesty , integrity and have not falsified or misinterpreted data in any form. The thoughts expressed herein remain the responsibility of the undersigned author and have no bearing on or does not represent those of Industrial Design Centre, IIT Bombay.



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Approval

The Design Research Seminar Project entitled “Structures in Nature” by Shefali R Ugavekar, is approved as a partial fulfilment of requirements of a post graduate degree in Industrial Design at IDC, IIT-Bombay 2015-17.

Project Guide:

A handwritten signature in black ink, appearing to read 'Balaram', is written over a light blue rectangular stamp. The signature is fluid and cursive.

Acknowledgement

I would first like to express my heartfelt gratitude to Professor VP.Bapat, my project guide, for his support, mentorship and guidance throughout the project. I would like to thank the staff of IIT Bombay nursery who helped me to find the bird's nests for the project. I am thankful to my friends and classmates for their support and suggestions throughout the research.

Abstract

Structures are the integral part of our world. Our nature is full of such inspiring structures. The man-made structures are often derived or are inspired from the natural structures. This research focuses on studying these natural structures present in nature, picking one of them, studying thoroughly and coming out with creative applications of that structure.

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BRIEF

Using nature as a model for inspiration, many new structure designs are evolved and used very efficiently. Take up one example or area from nature, search for applications already in use or developed and come out with new creative applications.

Structures



Fig.1: Natural Structures



Fig.2: Manmade/manufactured Structures

Structure is something that is constructed/built by joining parts to meet certain need/ perform a specific task. They can be natural or human made structures.

Material structures as shown in fig 2 include man-made objects such as buildings and machines and natural objects such as biological organisms, minerals and chemicals which need structure or skeleton to hold up every piece they are made of.

The structures in nature can be seen everywhere on the earth. Structures are not new. Nature produced the structure long before humans were able to. Every natural form has some structure attached to it which allows them to grow and it supports its life throughout its journey. Structures are found in flora and fauna, living or dead, sun or moon, and water or air. These are in the form of ribs of leaves, branches of trees, fins of a fish, ribcage of a human, beak/feathers of a bird, flow of a waterfall, nest of a bird, anthill of the ant, seashells, eggs cobweb etc. Refer fig.1 for natural structures.

Natural Structures

Man-made Structures

Mass Structures

Frame Structures

Shell Structures



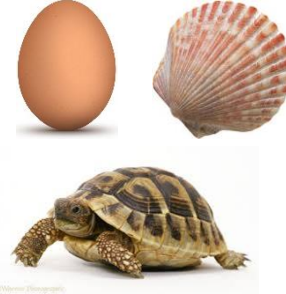
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They rely on their own weight to resist load.



https://s3.amazonaws.com/classconnection/932/flashcards/9241932/png/natural_shell-150027AA60866F08006.png

They are made from many small parts called as members which are joined together.



They are made to assemble as one piece

Flexible structures

Rigid Structures



Classification of structures

A structural system is the combination of structural elements and their materials. It is important to be able to classify a structure by either its form or its function, by recognizing the various elements composing that structure. The structural elements guiding the systemic forces through the materials are not only such as a connecting rod, a truss, a beam, or a column, but also a cable, an arch, a cavity or channel, and even an angle, a surface structure, or a frame.

As seen earlier, structures are natural as well as man-made. These structures can be classified according to the element that supports it. Classification of structure further leads to Mass structure, Frame structures and Shell structures as shown in figure 3.

Fig.3: Classification of Natural structures

Type of forces acting on a structure

Tension

Stretches/ pulls apart

Tensegrity is found in structure
e.g. cob web

Compression

Shortens and crushes the
structure

E.g.: Phenomenon of formation
of sand and pebbles

Torsion

Twists

E.g.: Cyclone, creepers use this
force to grow

Shear

Pushes parts in opposite
direction

E.g.: The phenomenon of shear
between tectonic plates resulting
in earthquake and formation of
continents

As opposed to man-made structures, natural structures are those forms that stand on their own and take a specific configuration but are not made by humans, including things like beehives, rock arches, canyons, eggshells, bird's nests, coral reefs and naturally formed caves. Natural structures are created from the Earth's natural forces or through the efforts of animals.

All structures do any of the following tasks:

- Support to hold something upright eg. Bird nest, trees
- Span a distance or reach across a gap eg. Cobweb,
- Contain or protect something e.g. sea shells, turtle shells
- Shape objects or some natural element

Examples of structures inspired from Nature

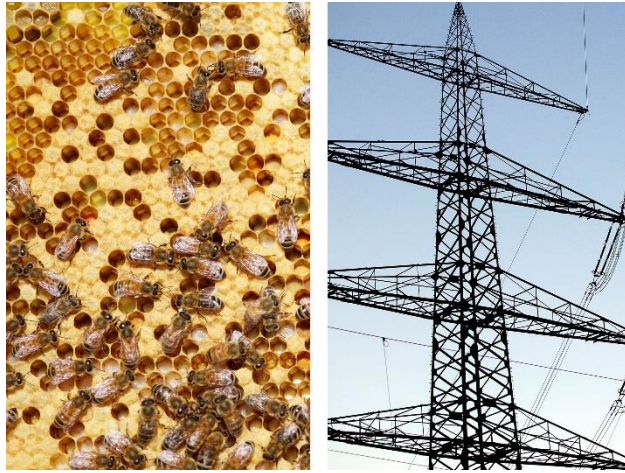


Fig4: Beehive and electric towers

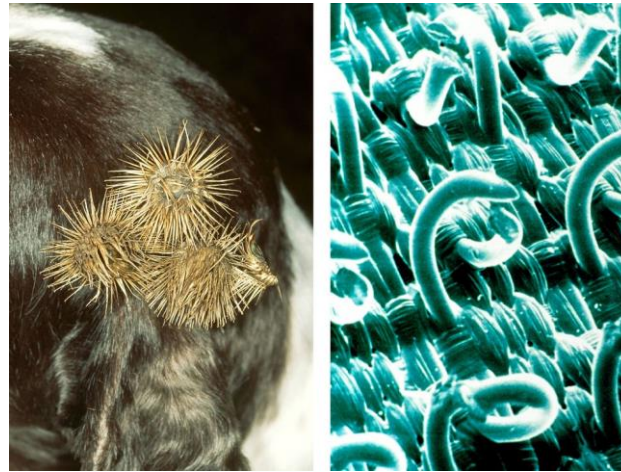


Fig5: Burdock burr and velcro



Fig.6: Namibian Beetle and fog collector



Fig.7: Kingfisher and bullet train



Fig.8: Humpback whales and turbine blades

<https://www.bloomberg.com/news/photo-essays/2015-02-23/14-smart-inventions-inspired-by-nature-biomimicry>

Figures shown above are the implementation of bio-mimicry i.e. from natural structure too man-made structure.

Bird's Nest

After studying various structures in nature, as shown the figure, I was fascinated to see how Birds nest has influenced so many structures available in the modern world.

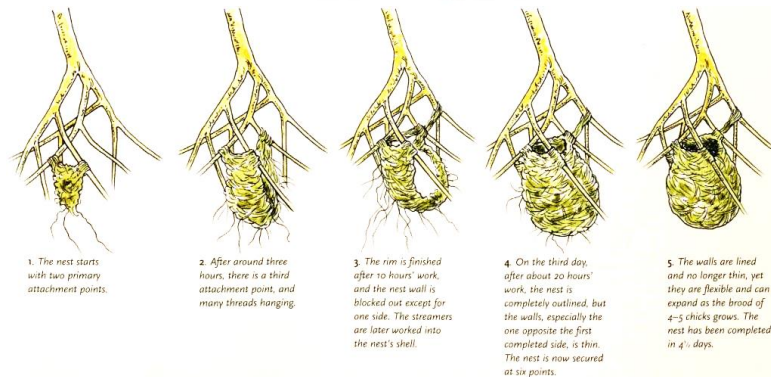


Fig.9: Process of bird's nest building

http://i1136.photobucket.com/albums/n498/raxacollective/book_BAOR/nestdiagram_zps99ec06e7.jpg

A **bird nest** is the spot in which a bird lays (fig.10) and incubates its eggs and raises its young. For some species, a nest is simply a shallow depression made in sand; for others, it is the knot-hole left by a broken branch, a burrow dug into the ground, a chamber drilled into a tree, an enormous rotting pile of vegetation and earth, a shelf made of dried saliva or a mud dome with an entrance tunnel. The smallest bird nests are those of some hummingbirds, tiny cups which can be a mere 2 cm across and 2–3 cm high. At the other extreme, some nest mounds built by the dusky scrub fowl measure more than 11 m in diameter and stand nearly 5 m tall.



Fig.10: position of egg in a nest

Type of Bird's Nest

Scrape nest

Shallow depression in soil or vegetation. A rim deep enough to keep the eggs from rolling away, is sometimes lined with bits of vegetation, small stones, shell fragments or feathers. Provide insulation or help to camouflage the eggs, prevent them from sinking into muddy or sandy soil. Refer fig 11.



Fig 11: Scrape nests

Mound Nest

Construct enormous *mound* nests (fig.12) made of soil, branches, sticks, twigs and leaves, and lay their eggs within the rotting mass. Size can be very large which contain more than 100 cubic metres of material, and probably weigh more than 50 tons.

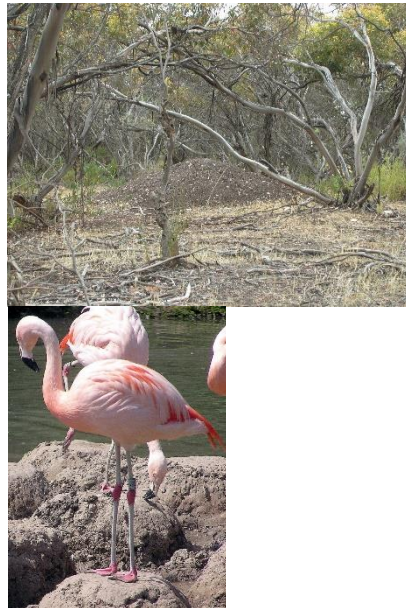


Fig.12: Mound nests

Burrow nest

Incubating parent bird- are sheltered under the earth. Soil plays a different role in the *burrow* nest (fig13). Common among seabirds at high latitudes, as they provide protection against both cold temperatures and predators. They dig a horizontal tunnel into a vertical (or nearly vertical) dirt cliff, with a chamber at the tunnel's end to house the eggs.



Fig.13: Burrow nests

Cavity Nests

A chamber, typically in living or dead wood, the trunks of tree ferns or large cacti. Cavities are normally excavated on the downward-facing side of a branch, presumably to make it more difficult for predators to access the nest, and to reduce the chance that rain floods the nest. line the cavity with soft material such as grass, moss, lichen, feathers or fur.



Fig.14: Cavity nests

Source: https://en.wikipedia.org/wiki/Bird_nest

Cup nest

The *cup* nest is smoothly hemispherical inside, with a deep depression to house the eggs. Many passerines and a few non-passerines, including some hummingbirds and some swifts, build this type of nest.

Made of pliable materials-including grasses- though a small number are made of mud or saliva. Fig 16 shown various materials used for building nest.

They also use spider silk in the construction of their nests.

Lightweight material is strong and extremely flexible, allowing the nest to mold to the adult during incubation (**reducing heat loss**), then to **stretch** to accommodate the growing nestlings; as it is **sticky**, it also helps to **bind the nest to the branch** or leaf to which it is attached.



Fig.15: Cup nest



Fig.16: Material used by birds to build nest

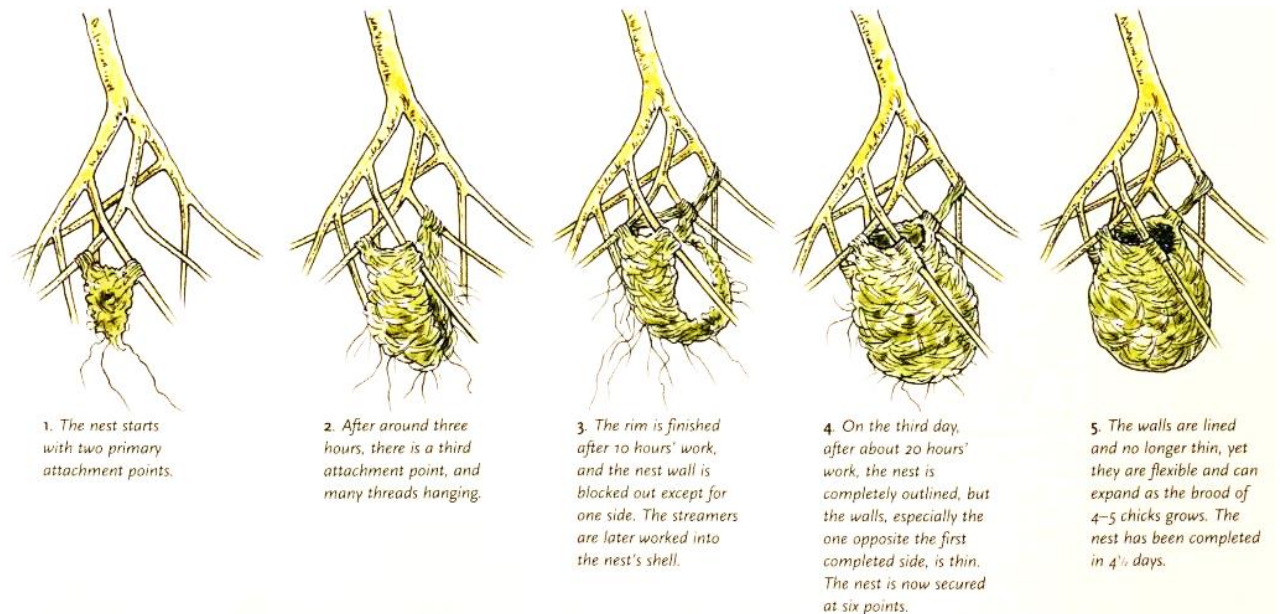


Fig.17 Process of bird's nest building

http://i1136.photobucket.com/albums/n498/raxacollective/book_BAO_Rnestdiagram_zps99ec06e7.jpg

Stages of construction

How Birds Build Their Nests

Mechanisms of nest building involve problems of selecting suitable nest materials, fastening the nest to the substrate, binding nest materials together, and shaping the nest to a durable and species-specific pattern. Nest building often takes much work, involving problems in economy of effort.

The significant cues whereby different species of birds recognize suitable nest materials need more investigation. Some birds have been known to build their nests of an artificial or atypical material—wire, glass, cotton, string, or cement. Fig 18 is showing the place where the cup nests are built which is on the v-shape between the two branches.

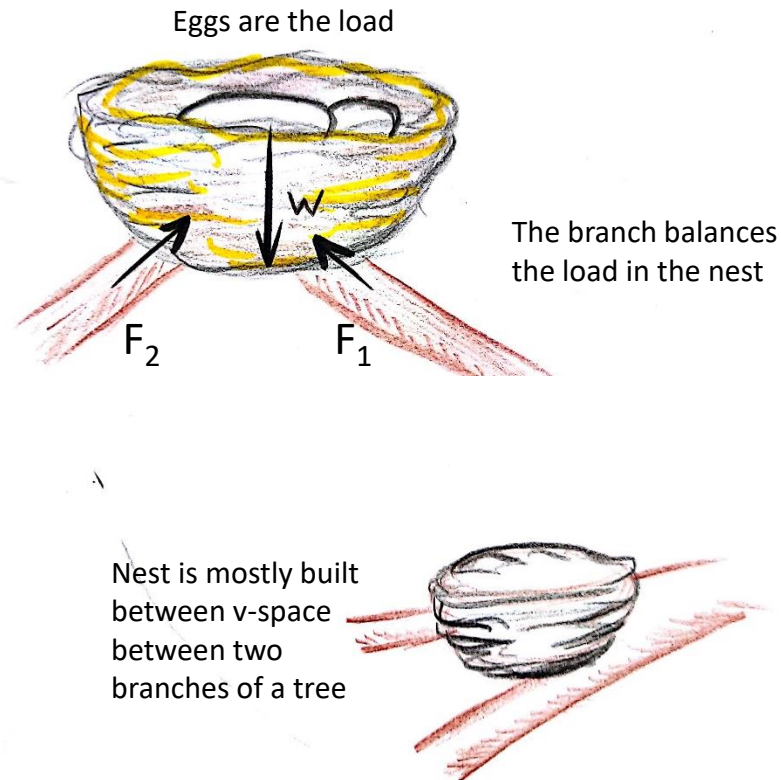


Fig:18 Selection of place for building the nest

Features of Bird nest:

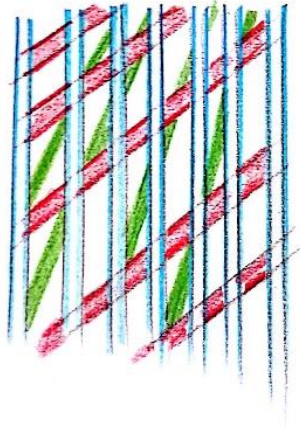


Fig. Layers in Bird's Nest Structure

Twigs are arranged in such a manner that they are flexible to stretch and compress.

- > Inclination
- Moderate Inclination
- Horizontal members

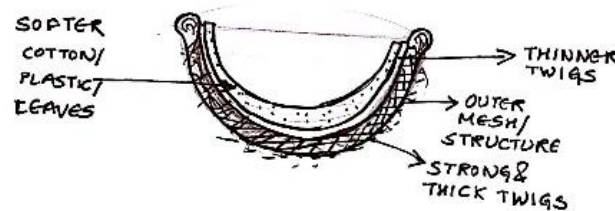
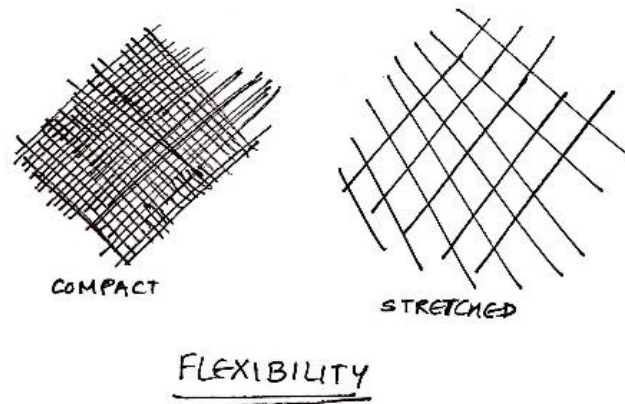


Fig:19 layers of construction



Cup Shaped: Space for the egg and the growing bird

Flexibility: to stretch the nest for growing nestling

Stickiness: To stick to the branch of the tree or leaves

Insulation: From heat and water

Porosity: To keep the ventilation open

Allometric relationship between the bird and the nest

Strong structure at base/ anchor

Levels of structure: Primary structure (strongest), secondary structure (supports primary structure), tertiary structure.



Sites for building bird's nest:

I tried to find bird's nest in the IIT Bombay campus and found 3 bird's nest, all cup shaped but of different sizes. Figure 20-1 was found at a very lower height of about 2 feet from ground and was mounted on the shrub (fig. 20-3) which had thorns on it to protect the nest from predators. The nest is made up of very thin wire like structure making a very light weight nest which denotes that the nest belong to a specie of birds small in sizes with small sized eggs. The centre of inertia lies at the bottom centre of the nest to support the eggs and prevent misalignment from the branch on which it is mounted.

Similar cup nest is shown in figure 20-4 where twigs along with artificial threads are used by the bird to build their nest. The nest was built on the branch of a tree around 7 feet from ground.



Fig 20. Bird's nests observed in the IITB campus

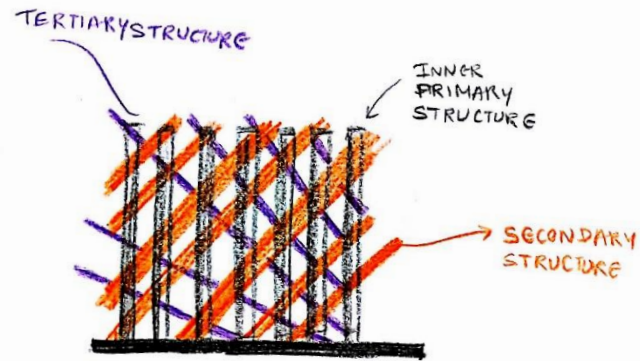


Thick twigs form
the main frame
of the nest

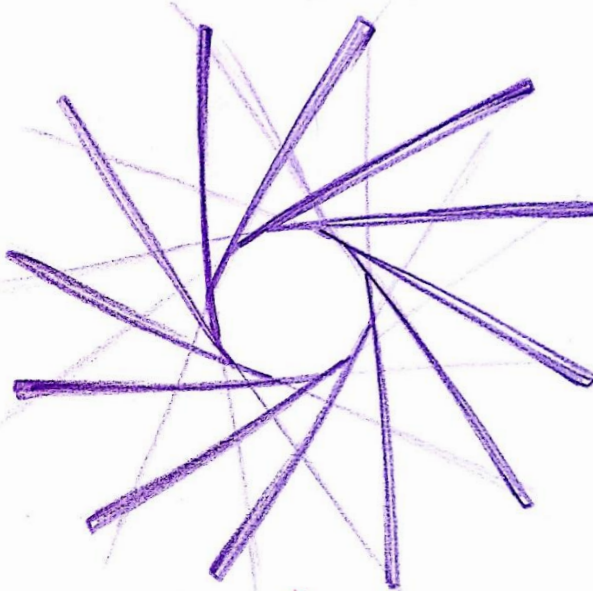
Thin and wiry twigs
act as cushion and
are on inner side of
the nest



Fig.21: Measurements of Cup shaped Bird's nest

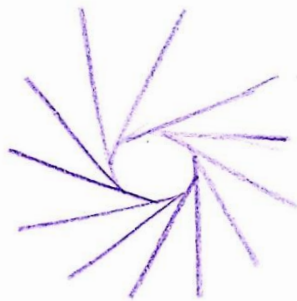


Layers of structure in a nest

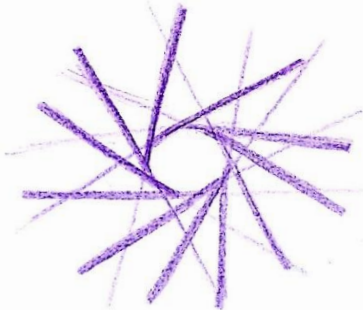


There are 3 layers of structures in the nest as shown in fig 22: Inner primary structure, secondary structure and finally tertiary structure. All three uses different types of twigs.

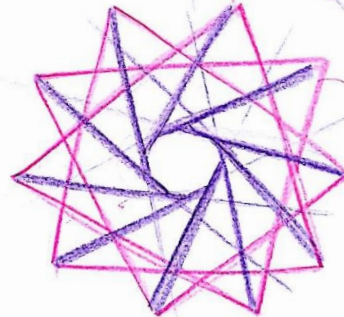
Weaving of cup shaped bird's nest is similar to the structure shown in the figure. The weaving of thicker twigs is done in this manner. Initially the twig is fixed at one end and twisted and weaved onto other twig.



Initial primary layer made by using thick twigs



Adding next layer of twig by weaving into primary structure



Tertiary layer of grass, binders, adhesives etc

WITHOUT CHAOS

Courtesy: Author

Fig. 22: Patterns due to weaving in a cup nest

Historical context of inspiring from nature

It has been seen since ancient times that the huts were made in a similar manner as the bird builds its nest. For example, weaving has been discovered and used extensively in many cultures as the main structural form. Though profound in its effectiveness in providing shelter, it is a very simple way of weaving sticks in a lattice framework, insulating it with mud and clay, and sometimes waterproofing it with animal dung. The weaving was also inspired from the way the birds weave their nests. Below (fig24) are some examples of loops and weaves that have been found in nests around the world.



Fig23: Mud huts

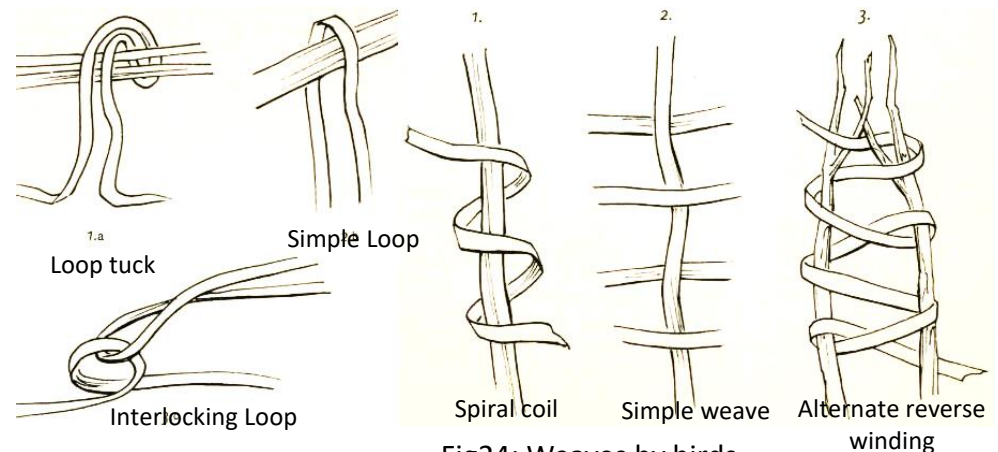
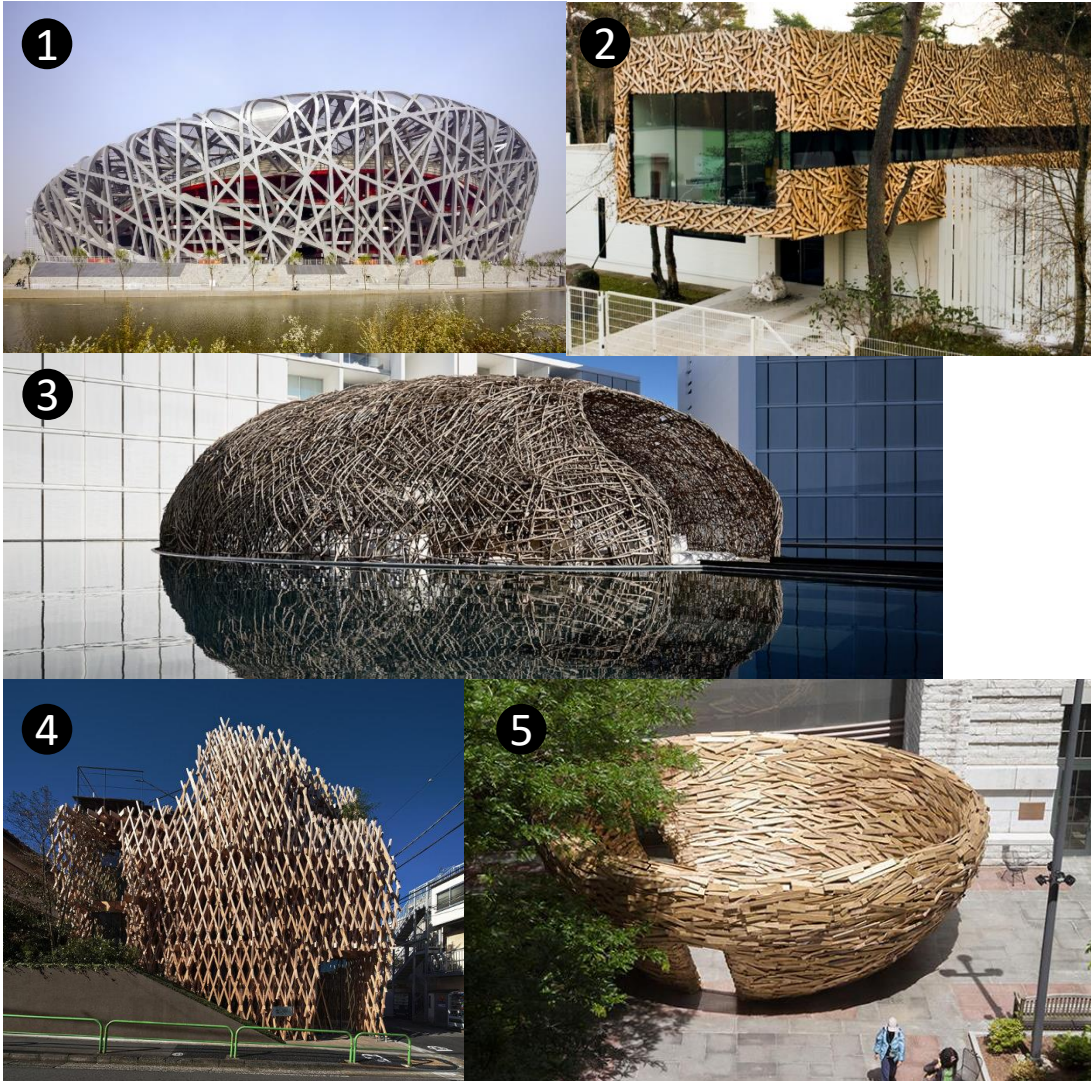


Fig24: Weaves by birds

Architecture



One of the most famous example of architecture is Beijing Olympic Stadium 2008 ^[1] which uses biomimicry of a Bird's nest. Hence has also being named as bird's nest stadium. Some architecture models ^[4] use the traditional Japanese techniques to build the structures ie., "jiigokugumi", which doesn't make use of nails or glue.

Floating restaurant in Mexico shaped like a bird's nest is an excellent example of inspiration from bird nest where it showcases properties of bird's nest like ability to float in water due to lightweight material used in construction, weaving structures to form the bird nest shape.

Angular bird's nest architecture ^[2] changes the stereotypical assumption of curvy bird's nest. This uses the wooden planks to construct the clutter as seen in bird's nest keeping the property of porosity intact.

The Reading nest ^[5] is an installation of an outdoor library for the public which lets you read comfortably in the nest. The nest is build using wood planks forming a chaotic yet cup shaped form.

Fig25.: Architectural examples of bird's nest Ref. www.google.com

Furniture

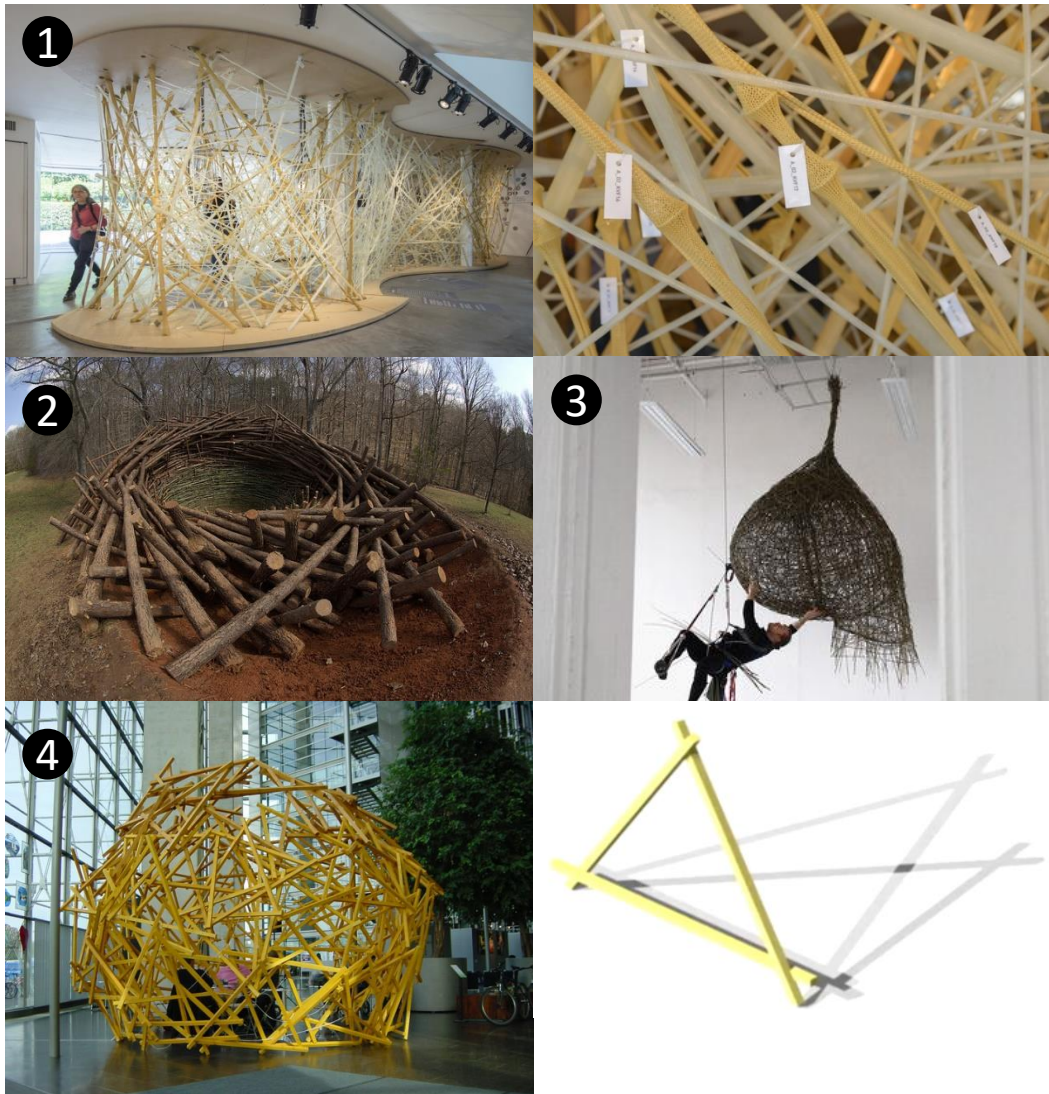
Bird's nest is often used by furniture designer to get inspiration from. A variety of techniques have been used to mimic nest into a furniture. As seen in image 1, 2, 3, the furniture is made by not using nails or glue, they are packed together in such a way that it does not come out. As seen in 2, the chair looks like it represent chaos, yet it looks comfortable to the person who sits on it, it looks flexible and cosy.

There are some designs which uses the features of hanging the product on the tree, which is an important feature of bird's nest, Finally making a hanging furniture. The main supporting structure makes the rim and primary support.



Fig26.: Examples of bird's nest in furniture

Installations



Lifeobject exhibition installation ^[1] uses the structure developed by 3d scanning a bird's nest composed of synthetic and natural material. This structure reacts to the body heat and movements of the visitors and integrates artificial and natural elements into its organic system. The bird's nest is made of synthetic fiber composites (frp) that are structured similarly to all living matter. An 80-Ton Bird's Nest ^[2] Built at the Clemson University Botanical Gardens. Human bird ^[3] is the installation build by the artist by mimicking a bird. The nest hangs in air and it is build in the similar way the bird builds it. Bird's Nest ^[4] looks chaotic, it is made of a single, geometric, triangular shaped wooden "module". In the "Bird's Nest" structure, the arrangement of the triangular "modules" in a semi-chaotic manner creates a space which is more organic – and rooted in structures found within natural systems.

Fig27.: Installations inspired from bird's nest

Lighting



Bird's nest have a very important feature which is hanging on the tree. Inspired from this feature are developed many lighting devices and lamps which may be hanging or may be suspended on a surface. Most of the times, wood or bamboo is used to mimic the elements of the bird's nest. These lamps have their elements arranged in semi-chaotic manner to match with nest. Making the lamp shade in tis manner serves as a good element for indirect lighting.

<http://www.dhresource.com/0x0s/f2-albu-g3-M01-42-1F-rBVaHVYwPI-AU4GIAMBLi55Srs443.jpg/creative-modern-simple-personality-blue-bird.jpg>

Kitchen Products



Baskets



Exhaust

As seen from the images below in fig 29, the bamboo baskets are totally inspired from the way the nests are built by weaving. The features such as having rim at the top and having mesh are all borrowed from nest design. They are all used to store something as in case of birds, it stores eggs.



Bamboo baskets

Fig29.: Examples of bird's nest in kitchen

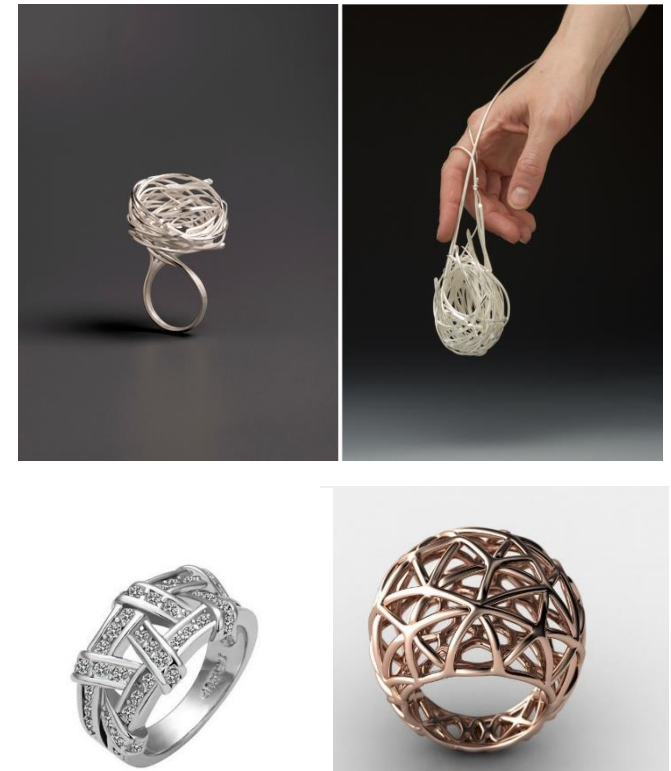
Stationery



Some of the products where it uses the property of bird's nest "clutter" to make it look like bird's nest. The mesh in the product is inspired from the mesh in the bird's nest.

Jewellery

Celebrating the clutter seen in bird's nest to make jewellery by techniques showing weaving, hanging feature, chaos.



Logo and bird's nest



Logos of company which sell property, housing or architectural design often use bird's nest structure as their inspiration. For the reason such as Bird's nest is a symbol of "home", "care", "comfort" and "Luxury". Café use these as inspiration to symbolise their café to the comfortable place for the public to reside. Bird's nest are used in abstract form to make logos.

Fig31.: logo design inspired from bird's nest

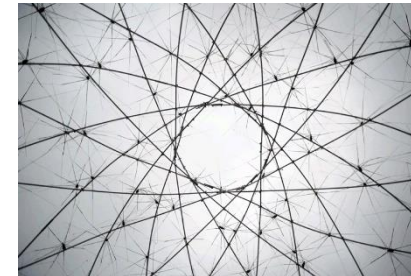


Baby Nest

Baby nest is inspired from the Bird's nest. It has the similar structure with a rigid rim for the baby to not come out of the nest, softer base for baby's comfort and flexibility due to softer material.



Fig: Net structures



Structure of umbrella

Net have a similar property as that of bird's nest. Nets are flexible, has high strength and take the shape of the thing that comes in contact.

Umbrella structures are also the mesh of straight members which can be transformed easily.

Building process of a weavers nest

Weaver birds are the great experts. It's the male bird who do the building. The process is shown in fig 33.

Ref: <https://www.youtube.com/watch?v=6svAlgEnFvw>

Step 1: To tie a leaf strip onto a twig. Its not easy for the fibre is very springy. The trick is to keep a firm hold on it with one foot and then they tie a knot with their beak.



Step 2: To weave a ring. The ring has to be big enough to allow its maker to sit through. And not allow larger birds and some animals such as snakes to go through. The strips have to be fresh and subtle.



Step 3: Once the ring is complete and firm, work starts for the roof. Their technique is the same as used by human weavers. A strip is threaded alternately about a willow and the strips are at a right angle to it.

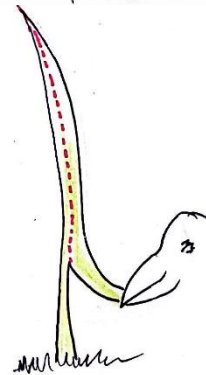
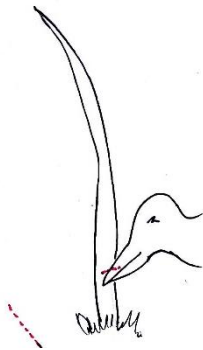
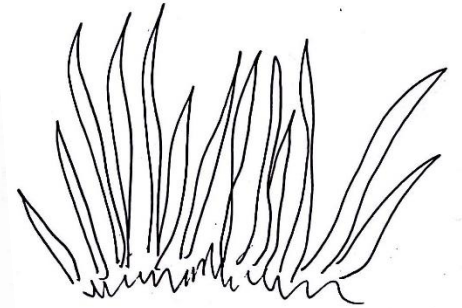
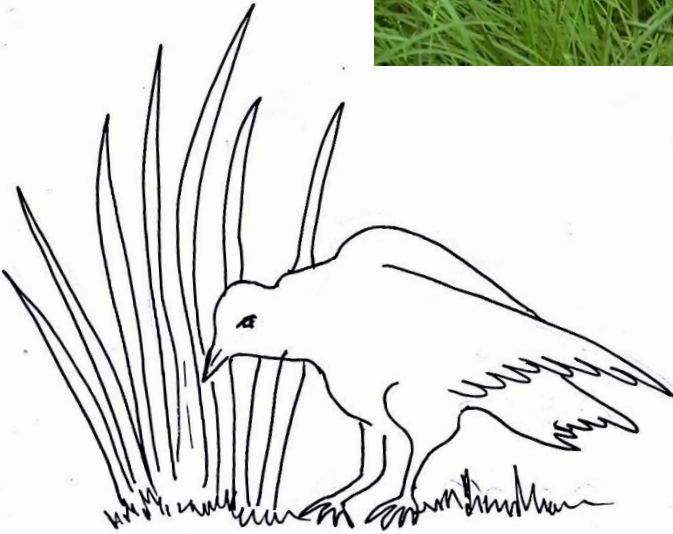


The whole construction is completed by adding a rather looser weave along the downward pointing entrance tube. This tube deters unwanted visitors.

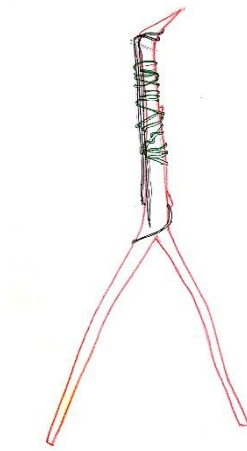
Fig33.: Process of weaving a weaver's nest



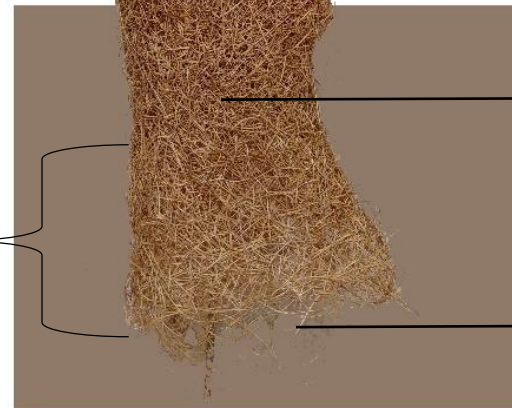
They get the suffice from the patch of grass nearby. They tear off the strips by gripping the side of the grass blade close to the ground and the separate by flying straight out. Over thousand of strips are needed for a single nest.



Tearing the whole strip by just flying straight out



Loose weaving
for flexibility
while entering
the nest



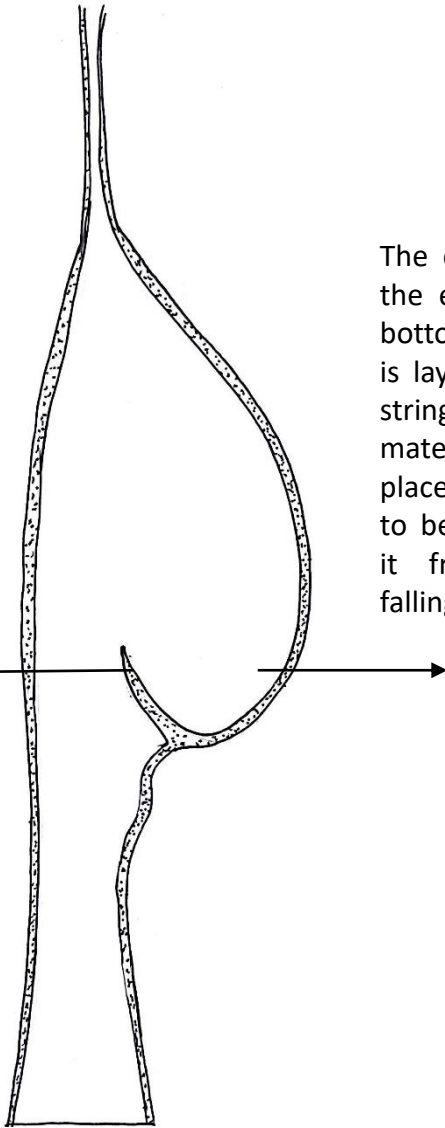
Chamber for laying eggs is oval shaped with a oval base, where layers of finer strings of grass are placed to make the cushioning for the eggs and chicks. In many cases, materials such as cotton fibres, and artificial items like plastic sheets have also been found in the nest to produce extra cushioning

Tunnel for birds to enter. Size of the tunnel equal to the size of weaver bird. It is not bigger than the size of the bird to make sure that the predators such as snakes and other birds do not enter the nest and destroy the eggs or harm the chicks.

Tunnel opening

Fig 34.Functions of different parts in a weaver's nest

An edge where the bird stands for feeding the chicks. It also acts as a boundary for preventing the eggs to topple down or for preventing the chick to fall down the via tunnel.



The chamber is where the eggs are laid. The bottom of this chamber is layered with circular strings of grass and soft materials to make a place suitable to eggs to be laid and prevent it from toppling or falling down.



Nest tunnel is almost the size of the bird

Bird can sit on the wall inside the nest to keep an eye on the eggs

Bird can sit on the wall inside the nest to feed the chicks

Observations from a weaver's nest



Fig.35.: weaver's nest



Fig.36.: location of weaver's nest

The nest in figure.35 is weaver bird's nest. According to the locals, these type of bird's nest are built on a branch of a tree which hangs above a well (fig 36). The reason for this is to prevent the snakes or any other animal to reach the nest and destroy the eggs. Had paddy straws inside it (fig.37). The nest was found in near the paddy farmers house. There were paddy straws lying all around the place. Which also indicates that the nest is made up of the grass/leaves available locally..



Fig.37.: Traces of paddy straw on the nest

The understand more about what is the construction inside the nest, was cut vertically from 1 side and the internal was observed as shown in fig 38



Fig.38.: weaver's nest cut into half

Paddy particles found inside the nest

It was found that there is a circular, cup-like weave inside the nest shown in fig.39. The circular structure is the place where the eggs were laid by the bird. The material used for weaving this is very fine fibres.

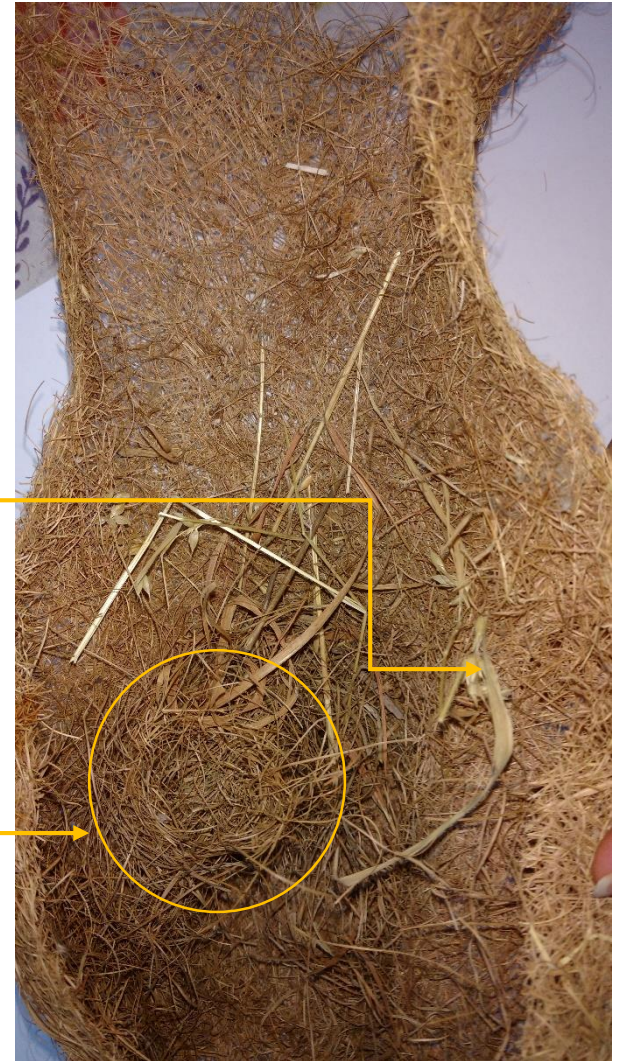
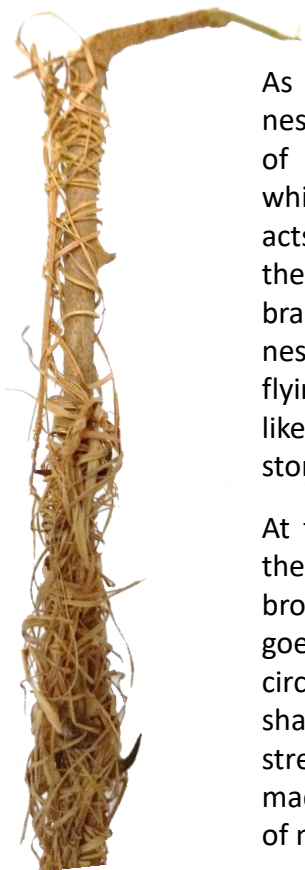


Fig.39.: internal of weaver's nest



Fig. Weaving in the tunnel like path from where the birds enter the nest

In a birds nest, the grass strings are weaved in such a way that they provide light and air to go through. Ventilation is very important for the bird and the chicks to survive at early stages of their life and these loose flexible weaves provide them efficiently without hindering the activities and movements inside the nest.



As seen in the fig(40), nest becomes the part of branch of a tree, which strengthens and acts as a pillar on which the nest is build. This branch of the tree help nest to get saved from flying off the tree in case like heavy wing, rain and storms.

At the v-shaped branch, the nest starts to get broaden which finally goes on to become a circular cross section. V shaped branch gives strength to the ring made in the initial stage of nest making.

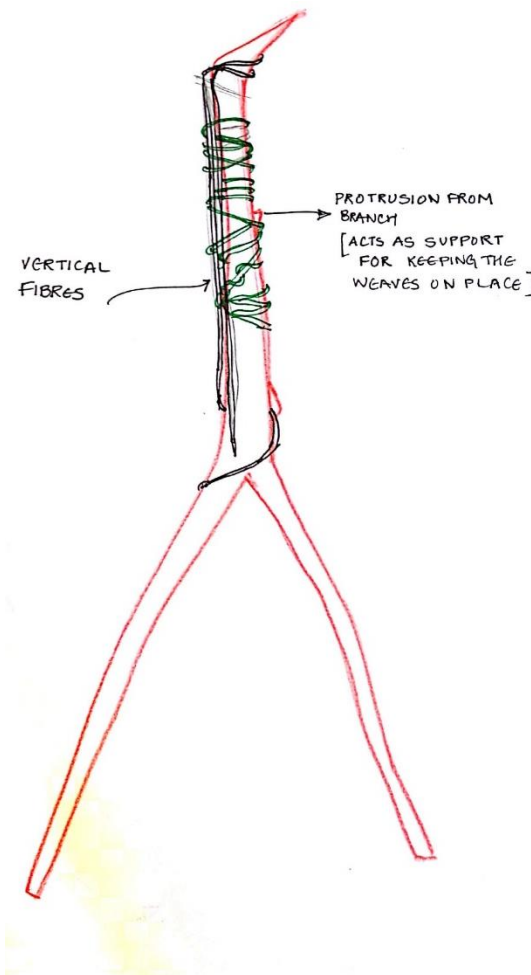


Fig.40: Location where the nest is started

To understand the weaving and on the outer surface of the nest, I tried to locate a grass strip, its position and length, which finally gave me the output in the form of span in which a single strip is distributed on the nest.

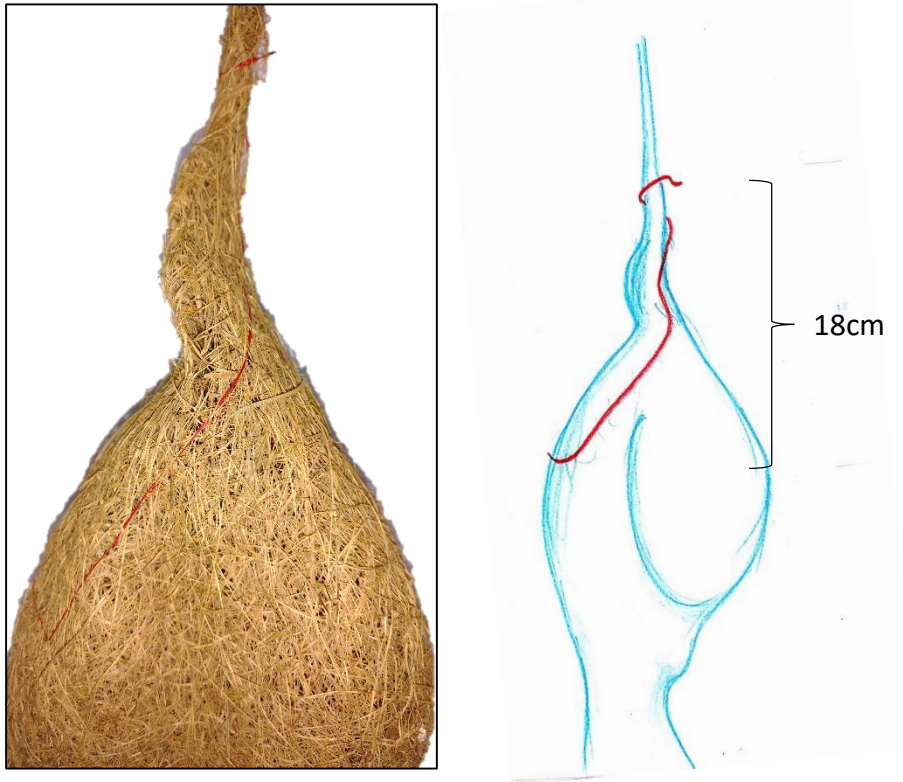


Fig: 41: Case 1 Locating the path of single strip

Case 1

The length of the strip came out to be 26.8cm and the vertical span on nest where it travelled was 18cm from top end to bottom end.

This study tells us that a fibre is not weaved in a specific concentrated area, it expands to a bigger area on a nest. Hence contributing to the a secure nest.

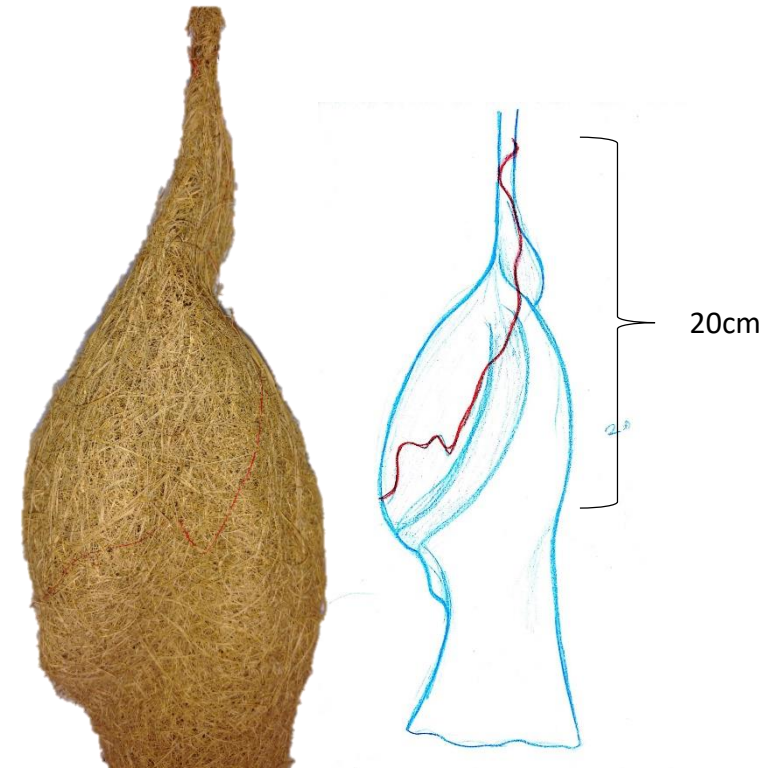


Fig: 42: Case2 Locating the path of single strip

Case 2

The length of the strip= 28cm and the vertical span on nest where it travelled was 20cm from top end to bottom end.

Creative applications of nest structure

Flexibility to develop a structure to save things from falling.

Flexible trampoline for kids

The random and mixed mesh structure to filter water

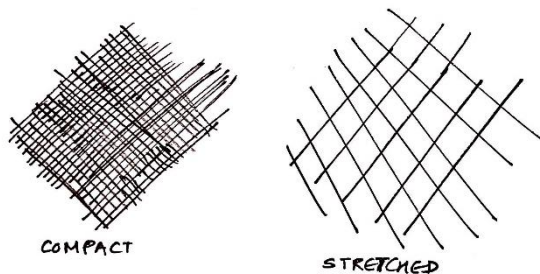
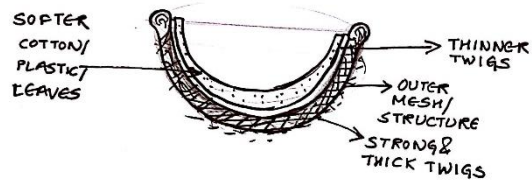
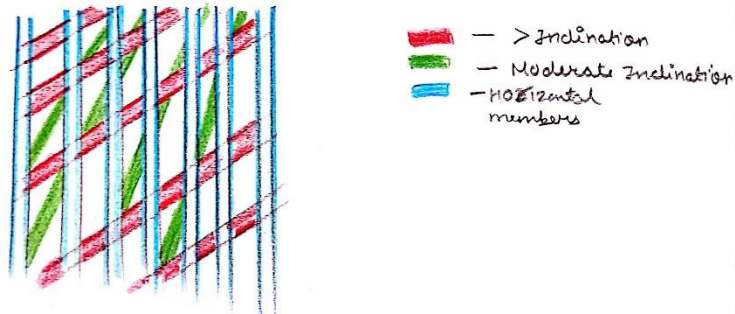
Some similar material to nest: Coir

Transformable furniture

Used as Suspension/cushioning for vehicles in uneven terrain

Floating structures in water

Ideations



FLEXIBILITY

Fig: 43: Features in a cup nest

TRANSFORMABLE FURNITURE

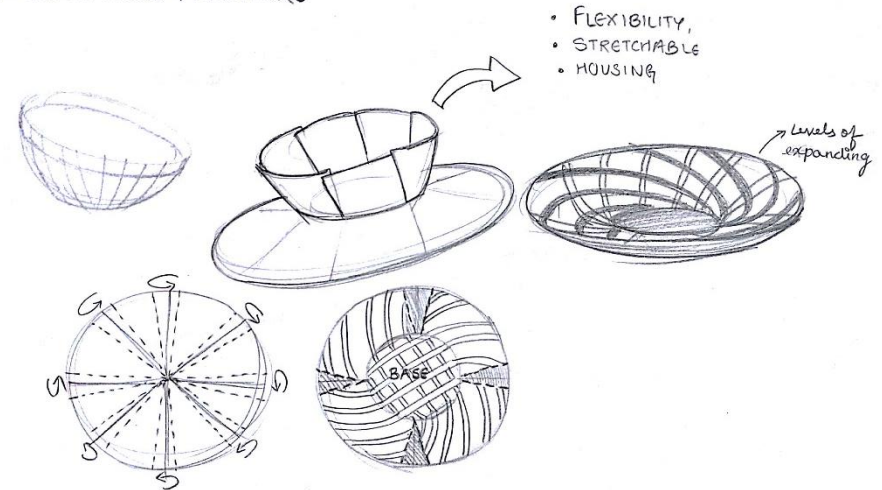


Fig: 43: Ideation 1: Transformable furniture

a) **Transformable furniture:** Incorporating the feature shown in fig.43 of bird's nest i.e; stretching the nest according to the growing nestling, The furniture can be transformed according to the shape of human. Or according to the need. Eg; a chair/ stool can be opened up to become a bed

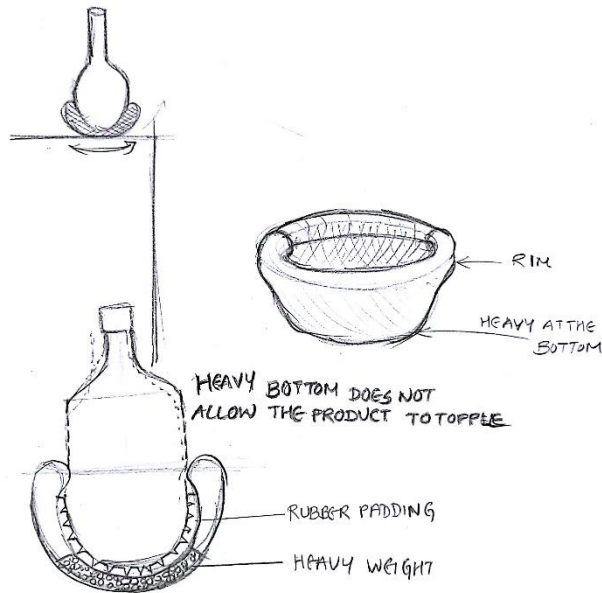


Fig: 44: Ideation 2: Bottle holder

b) Flexibility to develop a structure to save things from falling. Adding a weight to the bottom of the case will prevent the bottle/product to fall down or topple. The rim of the case will hold the bottle tight preventing it to move away. This can also be used in packaging industry.

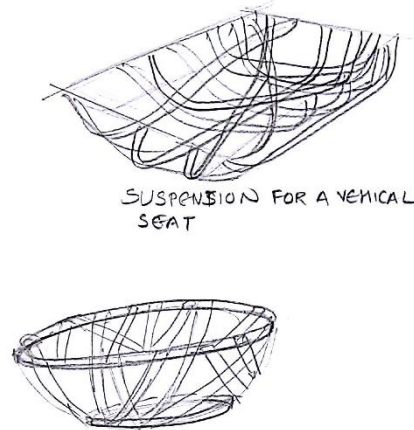


Fig: 45: Ideation 3: Heat dissipation using ventillation

c) A structure inside the vehicles for easy heat dissipation and efficient suspension. Structure inspired from bird's nest can be used in cars to support the engine and the other parts of the car as shown in fig 45.

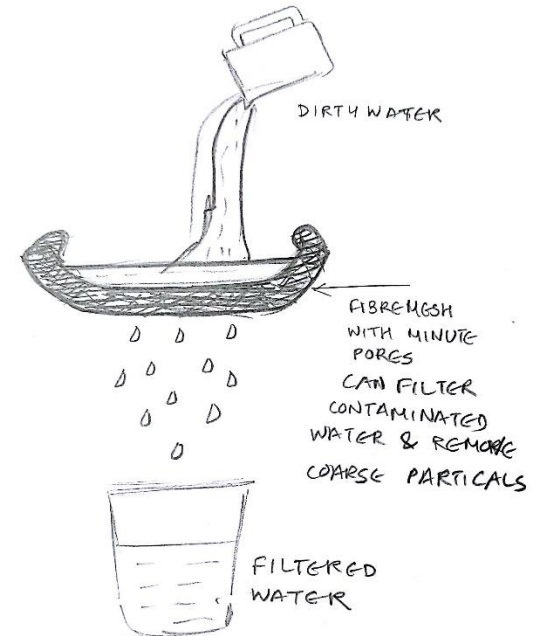


Fig: 46: Ideation 4: Use of similar mesh in water filter

Courtesy: Author

d) Filter water to remove coarse contaminations: Porosity is the feature of bird's nest which allows ventilation in the nest. In a similar way, this feature can be efficiently used to filter water and removing the coarse residues.

Conclusion

Structures in nature are immense in this space. To understand and create the possible application of specific natural structure, one must understand the purpose behind that structure's existence. In this project, bird's nest was taken up as the topic of research where understanding the nest structure, man-made structures inspired from bird's nest were studied and possible creative applications were ideated.

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