

Introduction

The Need

Most rural people in India both men and women defecate in the open they are seen squatting by the side of the road. India's high rate of open defecation takes the lives of hundreds of thousands of children each year. Children lose their life to diarrhea and other water borne diseases (Ref 1). Children who defecate in the open have the tendency of catching diseases sooner than the children who use latrines, these children are weak and are unable to grow to their full physical and cognitive potential. Although many people who defecate in the open think it is harmless, or maybe even good for them, they are wrong: the negative consequences of open defecation are a very big deal and can take their life because of the diseases it causes. Also women need privacy and extra hygiene to prevent themselves from various infections. Therefore it has becomes necessary to design and develop a low cost, simple and hygienic sanitation system. Educating people about the importance of good sanitation for their health and well being is very important.

Motivation of the project

In recent days, open defecation has been in the news because it is hoped that building toilets could reduce rape. Sexual violence in India is a tragedy. Survey conducted on thousands of rural households, men and women separately what they thought about toilets shows that using a latrine does appear to be more important to women than to men: in households with a latrine, women are more likely to use it than men. One reason may be that most of such women can only go out for defecation early in the morning or after dark, while most men face no such social constraints (Ref 2). Women go to the farms in a group so that one can keep a watch while the other is defecating. This does not only create a safety issue but also various health issues. Women require a lot of hygiene and privacy than men and they cannot go out alone in the open. This makes them dependent on others for such a basic need of using the toilet whenever they want. Such cases have highlighted the need to make a design intervention that would help people particularly women and children reap in the benefits of sanitation structure, which acted as the motivation of the project.

Initial design brief

To design a structure for sanitation for the rural areas.

- Low-cost structure.
- Parts should be easily replaceable.
- Local material.
- Low cost.

Scope of the project

This toilet structure design in the rural areas will eliminate the spread of diseases .Women will get the privacy they require and they won't have to depend on others to go to the toilet.

This toilet structure is meant for individual use or a small group of people living in the same house. This structure is made using rural material which makes it easily repairable, it can be easily carried by a person and deployed.

Features not addressed are:

- The fixing of the squatting pot along with the base structure.
- The disposal of waste excreta.

Design direction

After finalizing on the design brief, the various possible approaches or design directions to proceed in the project were jotted down, of which the 3 most prominent directions were:

- Usage of local material.
- Can be constructed locally.
- Easily deployable.

Of the above stated design direction, a rural approach was taken up, with an intention of taking up a design challenge that would help to solve the problem to sanitation in the rural areas.

Design Process

Design process followed

After the conception of the project area, the following steps were used to come up with a feasible end product:

Understanding of the project area:

Brief discussions with the guide were held where the area of work was focused down to a refined area, in that regard ample research on the sanitation situations and structures across India were studied to increase the knowledge base about the project area.

User details, material choices, ergonomics, existing products data, etc were collected which was later on helped understanding intricacies of the project and opened avenues for new opportunities.

During the study and data collection understanding the pros and cons of the sanitation situation in the rural areas of India was a important aspect of the project progress.

Design Process

Advantages of having a toilet:

Comfort

Privacy

Hygiene

Odour control

Convenience

Indoor use

Waste management

Disadvantages of having a toilet:

Lack of proper care and maintenance.

Improperly or poorly maintained systems can lead to odors, insects, and health hazards.

Design Process

- Tackling the initial obstacles:

The biggest challenge in the project was coming up with a solution that would cater to the sanitation needs of rural India keeping all the limitations in mind such as the weather conditions, grounding of the toilet, usage of rural material, deployable, product life etc. Considering all the above limitations the focus area changed to only the structure for sanitation. The design would include only the toilet structure and its joining details. The disposal of waste, squatting pot, waste pit, water connections are factors that have not been considered in this project. The structure would be Low-cost in terms of its life cycle (3-5 years) and also that it can be fixed where ever needed and can be folded and kept or carried when not required. Its made using rural material which makes it extremely local and the parts can be easily replaced incase of any damage.

- Choosing the target users:

Based on the research, the target users chosen were—

Low-cost dwellers of rural India, slums, Household usage

- Proposal of design brief:

Based on the insights obtained from the data collection, a few changes were made in the design brief, to get clarity of project structure.

Design Process

- Finding the design directions:

Domestic (household) approach.

Local methods(product made using locally available materials)

- Classification of the project area:

Based on the design directions the classifications made were broadly of two types:

System Level–permanent sanitation structure.

Low-cost(on the move)–products for population on the move, Low-cost dwellers, slums, etc.

Due to constraints like duration of project and resources available, the Low-cost(on the move) classification was chosen.

- Idea generation:

After the design directions and classifications were finalized, ideas were generated. A parallel product study and material study was done which helped in understanding the rural situation and made it easy to generate ideas.

Design Process

- Refinement of design brief:

At every stage of the project a new interesting avenue opened up, which improved the functionality and feasibility of the product—but also meant the design brief had to be modified many times.

- Concept generation:

After the ideas were made, the best of the ideas were taken together and structured in a manner that would give a workable concept at the end of the project.

- Finalizing the concept:

After the concepts are generated, a detailed concept evaluation is made over the most important features that is needed in the product and how each concept fare over the other. The winning concept is then finalized.

- Mock-up phase:

In order to understand the look, feel and working of the product, many mockups were built.

Design Process

- Detailing of the product:

Before making the functional prototype a detailing of the product was made and finalized ,which highlighted the flaws in the design,this lead to a more refined detailing in the further stages of the project.

- Material consideration:

A variety of materials were studied and considered for making the final structure. Both pros & cons of every material was studies carefully. Keeping all the factors in mind “Bamboo” was the proposed material for the final product as it is light weight, locally available, can be easily replaced, strong enough for making a structure, not expensive.

Factors taken into consideration for constructing the toilet structure

- Structure around the toilet pan can be constructed taking into consideration local construction material, labor available, availability of funds.
- Materials that can be used for constructing the structure of the toilet to create privacy are as follows :-
 - Bamboo
 - Cloth
 - Nylon fiber
 - Plywood
 - Cement Sheet
 - FRP panels
 - Red Bricks
 - Vegetation
 - Galvanized panels

Bamboo and Cloth

Bamboo can be used in various ways.

- Advantages :-
 - Can be locally constructed.
 - Structural framework can be done by bamboo sticks and it can be covered by weaving bamboo mats.
 - Parts easily replaceable.
- Disadvantages :-
 - Bamboo has a short life span.



Image 1

http://1.bp.blogspot.com/-MtiH9XlqzTo/UHkMlmgfZl/AAAAAAAKIM/IY9_EjflrM/s1600/small+bamboo+house+7.jpg



Image 2

<http://3.imimg.com/data3/YG/KY/MY-4735195285/bmb-500x500.jpg>

Cloth or any fabric are another materials that can be effectively used.

- Advantages :-
 - It is a cost effect material.
 - Can be easily changed or replaced as and when needed.
 - Readily available.
 - Frame can be made with some other material and cloth can be used to cover the frame to form the structure.
- Disadvantages :-
 - Life span of such structure would be less than one season.
 - Cloth can tear easily.
 - It would keep needing repairs and replacements.
 - The structure won't be very strong.



Image 3

http://www remodelista.com/files/styles/733_0s/public/img/sub/uimg/01-2012/canvas-drop-cloth.png

Nylon fiber and Plywood

Nylon fiber is also known as tent material. Small tents are made of nylon.

- Advantages
 - It is waterproof
 - Light weight
 - Durable
 - Easily available
 - Low cost
- Disadvantages
 - sunlight can shorten the life of the material



Image 4

<http://www.campist.com/archives/vango-milano-2-camping-tent.jpg>

Marine plywood can be used to make the structure.

- Advantages :-
 - Can be locally constructed.
 - Plywood or marine plywood can be used to make the wall of the toilet the frame can be made by using aluminum frames or channels.
 - Plywood is readily available and not very expensive.
- Disadvantages :-
 - Plywood may catch termites or insects which can make the structure weak
 - Plywood tends to get spoilt during rains.
 - Life span is very less.
 - Normal plywood lasts for a year and marine plywood lasts for 2-3 years

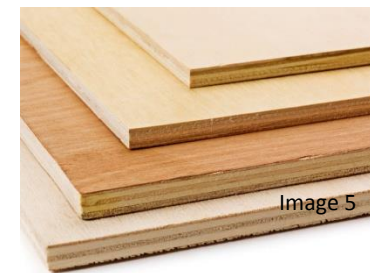


Image 5

http://www.finixia.com/commerce/wp-content/uploads/2014/02/PLYWOOD_MARINE.jpg

Cement Sheet and FRP Panel

Cement sheet can also be used.

- Advantages :-
 - Can be locally constructed.
 - Structure can be made of cement panels
 - Cement panels of different widths are readily available.
- Disadvantages :-
 - Life span of the panel is very short. Between 3-5 yrs depending on the usage.



Image 6

http://www.rolextimber.com/index.htm_files/304.jpg

FRP panels can be joined together to make the structure of the toilet.

- Advantages :-
 - FRP panels are clipped together using metal clips to make the toilet structure
 - Life span of this material is more than 20yrs.
- Disadvantages :-
 - Very expensive.



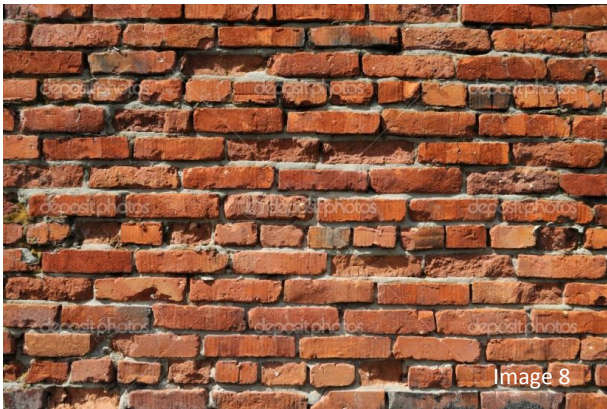
Image 7

<http://www.in.all.biz/img/in/catalog/267765.jpeg>

Red Bricks and Vegetation

Red brick walls can be made.

- Advantages :-
 - Can be locally constructed.
 - Material readily available
 - Construction cost is not very expensive.
- Disadvantages :-
 - It will be a fixed , permanent structure
 - Life span is very long.



<http://static6.depositphotos.com/1000681/607/i/950/depositphotos/6071168-old-red-brick-wall-background.jpg>

Plants can be grown in such a way that it covers the entire area.

- Advantages :-
 - Can be locally planted.
 - It is the most simple and cost effective way of making a toilet structure
- Disadvantages :-
 - There is a little less privacy in such types of toilets.
 - Plus there are chance of animals coming since it's very open.



<https://www.arborday.org/trees/privacyhedge/graphics/photos/1.jpg>

Field Study

- **Name** - Mirkutwadi, Sangdewadi district, Maharashtra.
- **NO. of houses** - 70
- **Population**- 350 to 400. (male population is more)
- **Main Occupation** - Used to be agriculture and fishing.
- **Current occupation** - Low-cost workers at adlabs imagica.
- **Per day salary** - Rs 250
- The village community is head by the sarpanch (village head man) who is elected every 5 years by the members of the village.



Image 10



Image 11

Field Study

Current village scenario:

- There no toilets in the village.
- The villagers go to the farms to defecate.
- Men and children go at anytime during the day.
- Women usually go in a group or early in the morning when everyone is asleep.
- As compared to the men, children and women often catch an infection or have other heath issues due to unhygienic sanitation.



Existing rural toilets in India



Image 14

<http://listdose.com/10-things-that-are-stopping-india-from-development/>



Image 15

<http://www.ruralhousingnetwork.in/technical/eco-san-toilets-for-individual-households/introduction>



Image 16

http://www.elamjung.com/local_view.php?id=1298

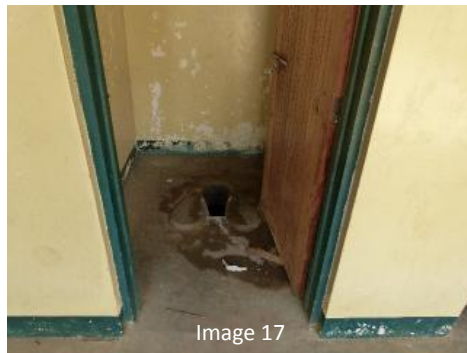


Image 17

<https://www.hands4africa.org/Sanitation/toilets.html>



Image 18

<http://srffoundation.wordpress.com/tag/toilets/>

Existing Low-cost sanitation structure Study



Image 19

http://farm4.staticflickr.com/3247/2730779169_d5887e3c88_m.jpg

These toilets are positioned over the canals. They are Low-cost toilets and can be placed over any canal and used directly. The idea behind this toilet is to dispose of the waste directly into the sewage. This has a lot of disadvantages. During the rains these canals overflow leading to a lot of dirt which causes diseases and infections.



Image 20

http://toiletsoftheworldbook.com/wp-content/uploads/2009/08/201_IND_tent.jpg

This is a Low-cost toilet tent erected using cloths and saris of the Indian women. It contains a concrete slab with a small hole, placed over a dugout with two tiny footpads on either side. This toilet is nothing more than a shallow indent in the ground.

Existing Low-cost sanitation structure



http://www.aljazeera.com/mritems/Images/2013/10/25/20131025151112470580_20.jpg

This is a Low-cost toilet made of bamboo poles and covered with poly propylene plastic. It is placed in the lake to dispose of the waste directly into the lake. This creates unhygienic situations as the same lake water is used for several other purposes like bathing, washing clothes etc. this leads to a not of diseases and infections



<http://www.bloomberg.com/bw/articles/2013-09-09/in-india-a-toilet-shortage-drains-the-economy>

This is a Low-cost sanitation structure in the slums. It is made of materials that the slum people could use and find. Like they have used a broken door as a path to enter the toilet. It is placed in the sewage canal.

Existing Low-cost sanitation structure



This is a Low-cost toilet installed in the villages of India. Made of FRP. It has a pit below it where the waste is decomposed. It requires constant cleaning & maintenance. This toilet has a squatting pot and is also called a bio- toilet.

Image 23

<http://media.newindianexpress.com/article589265.ece/alternates/w620/bio-toilets-PTI.jpg>

Existing Low-cost sanitation structure



<http://geekologie.com/2013/05/03/urine-hay-compost.jpg>

This is a urinal only for men. It has plastic containers attached to a bundle of hay. Men come and urinate in the containers and it gets collected in the hay and dries off due to the heat of the sun as it's kept in the open without causing bad odor.



<http://www.campist.com/archives/stinky-pete-shower-toilet-tent.jpg>

This is a Low-cost toilet tent. It is portable, can be carried easily from one place to another. It can be folded and kept when not in use. Mostly used by travelers.

Insights From Parallel Product Study

The research on various Low-cost toilet structures available gave an overview of possibilities with the area chosen for the project.

Few insights obtained from the study are as listed below:

- Understanding the current sanitation situation
- Material, manufacturing & installation of the Low-cost sanitation structure
- Usage of local material technology in building the structure in a way that it enhances the aesthetic value of the product.

The knowledge got from doing the product study gave an opportunity to get clarity in understanding the current situation and also helped in creating new concept.

Design brief

Based on the research and analysis done the area of designing was narrowed down to a precise design brief.

DESIGN BRIEF:

“ Low Cost sanitation structure for the rural areas in India”. Structure had to be Low-cost in terms of its life cycle and also that it can be fixed where ever needed and can be unfixed and moved or kept when not in use. It should be made using rural materials that are easily available locally. Part should be easily replaceable, easy to repair & maintained locally without being dependent on industrial tools and processes. The structure should be low cost and easy to deploy.

The structure should have the following features:

- Rural material.
- Light weight.
- Low-cost structure.
- Parts can be easily replaced, repaired & maintained locally.
- Low cost.
- Easy to deploy.
- Good stability

Target users

The target users were primarily the people of rural India particularly women and children. Women need privacy and extra hygiene to prevent themselves from various infections. Thousands of Children in India lose their life to diarrhea and other water borne diseases each year due to open defecation. Hence the focus of the project was to design a Low-cost structure for sanitation for the users living in a Low-cost dwelling in the rural area or in the slums.

A system level change to the permanent dwellers of rural India would mean a government intervention, large investment and more time would be required to look into various details which is not favored in the project period.

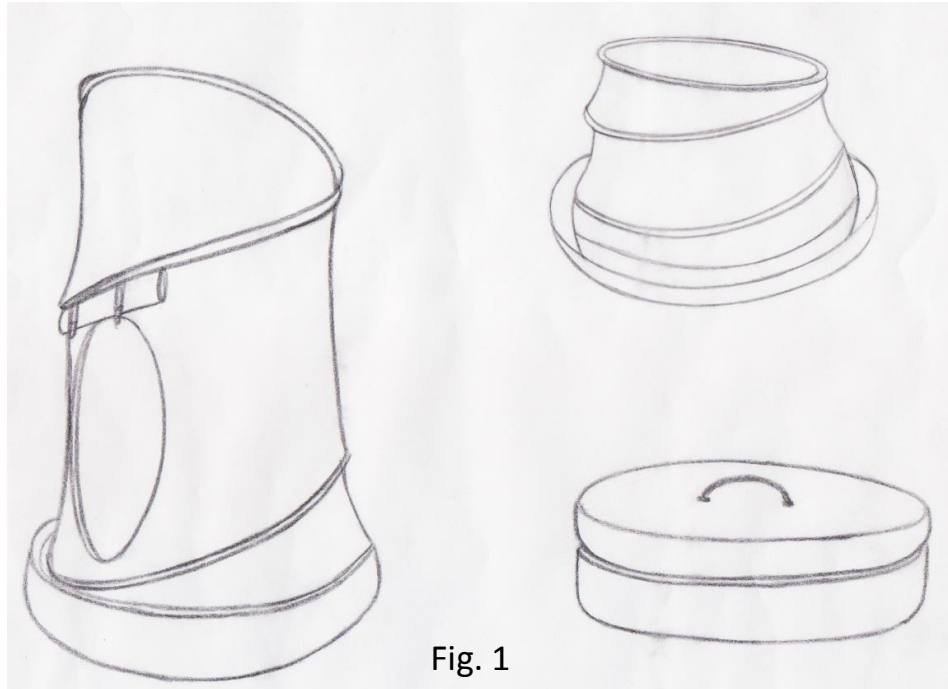
Ideations

Based on the analysis done on the parallel product study, target users and refined design brief, ideations were made taking into consideration of the various possible creative solutions.

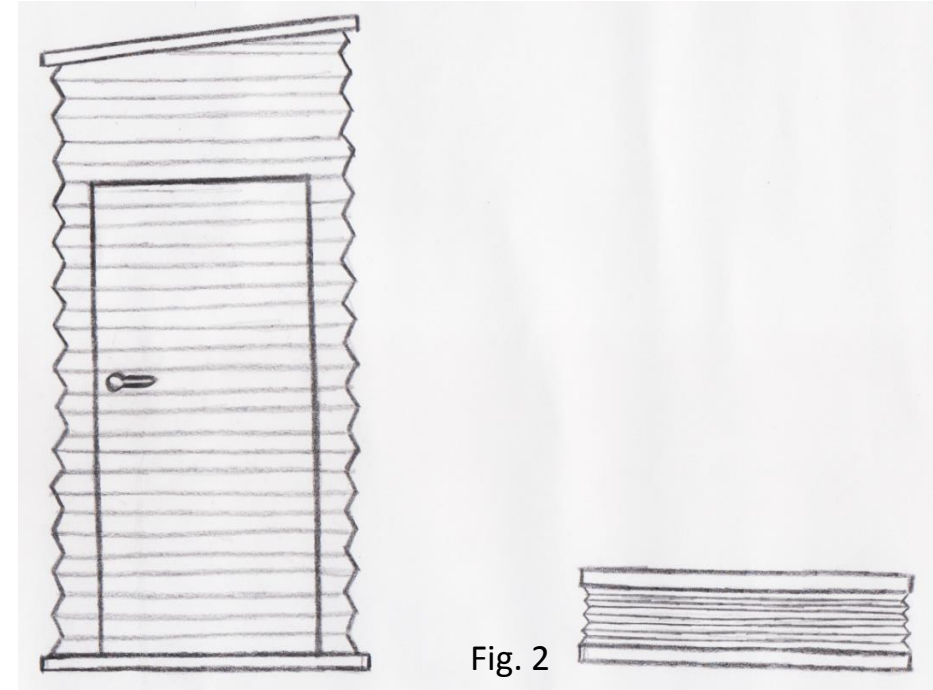
Ideations first started with sketching without ruling out any concept as impossible. These ideas were later refined more and more based on logical reasoning and feasibility aspects.

More refined ideations were made after many alterations, which very evidently started taking the form of product with many feasible aspects.

Initial ideations (Phase 1)



Circular Collapsible toilet. This toilet structure is portable and can be easily carried from one place to another. It can be folded and kept in a box (as shown in fig.1) when not in use. This particular toilet structure design was inspired by the foldable clothes laundry bag.



Collapsible toilet. Collapses and takes a shape of a box (as shown in fig.2) It is easy to carry. Can be folded and kept when not in use.

Initial ideations (Phase 1)

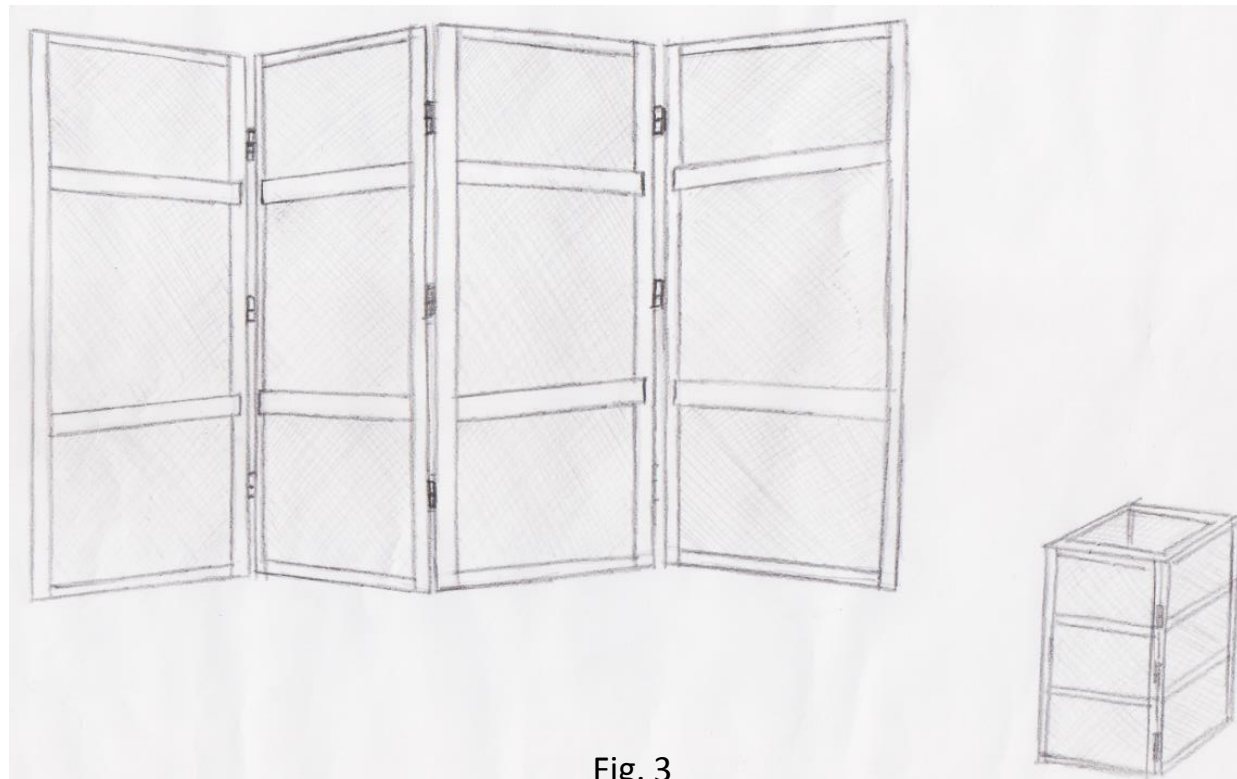


Fig. 3

Foldable structure that takes the shape of a cuboid. This structure is easy to package as it can be folded in a door like pattern when not in use. It can be carried from one place to another and is very easy to assemble and disassemble.

Initial ideations (Phase 1)

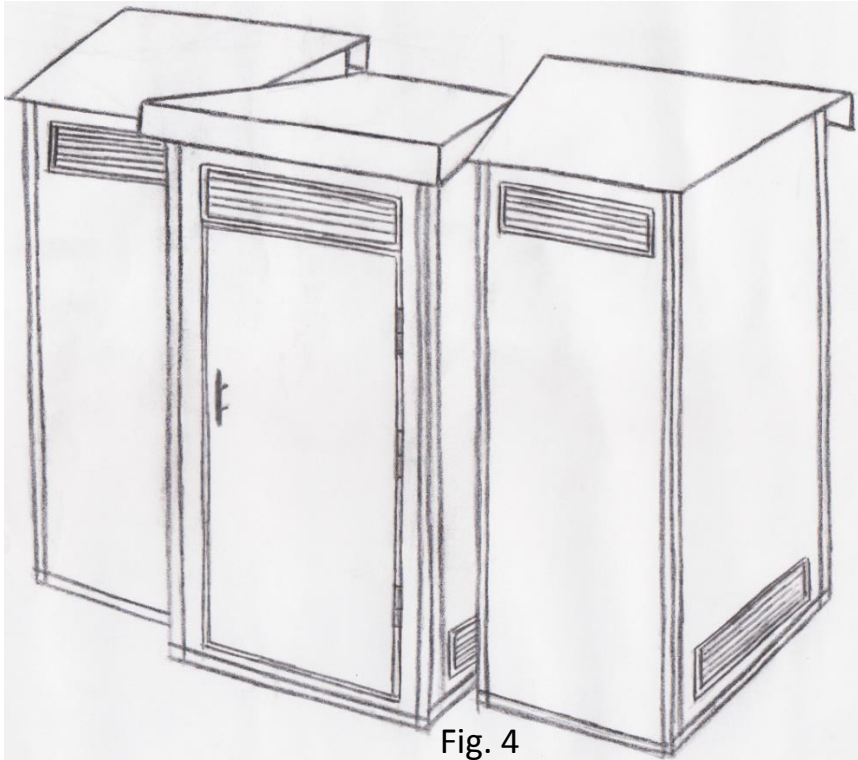


Fig. 4

Modular toilet design with a tilted roof to prevent the collection of dust and water on top. It has 4 ventilation ducts. 2 on each of the lower side of the toilet, one on top of the door and 1 on the back. This toilet was designed in a way that it could form a pattern in case 4-5 toilets were to be placed together.

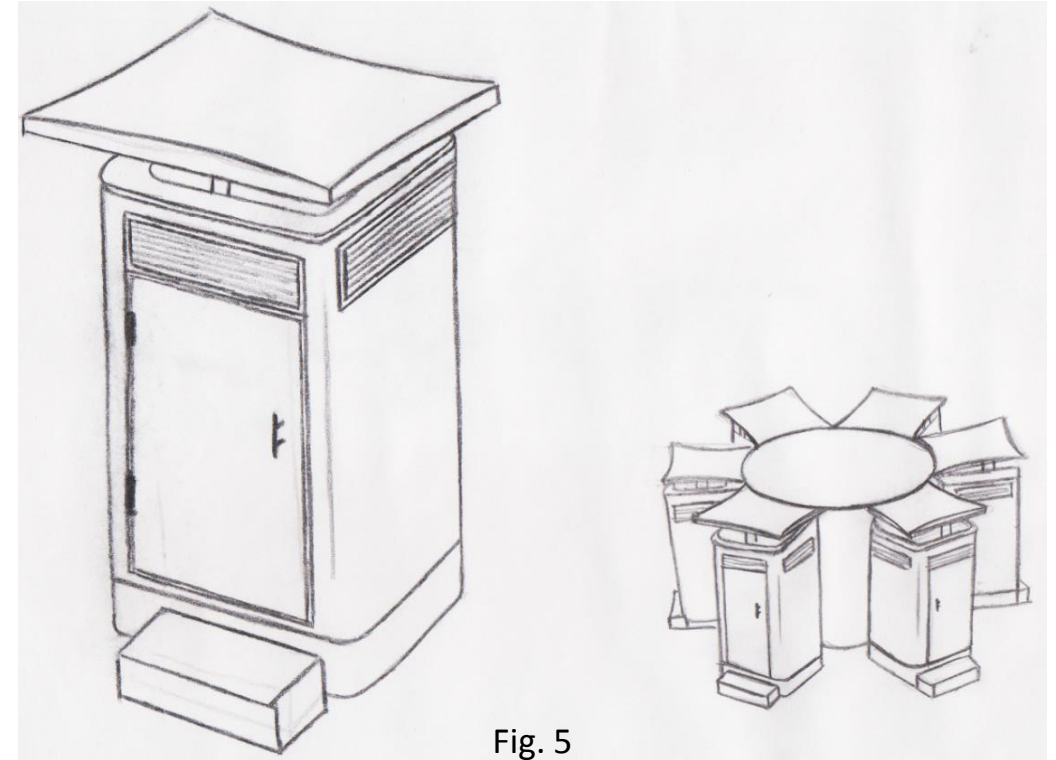
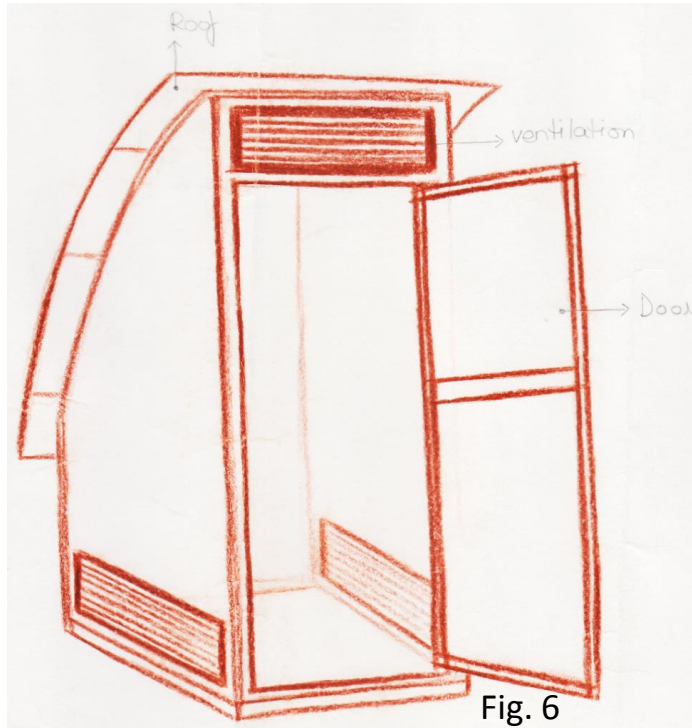


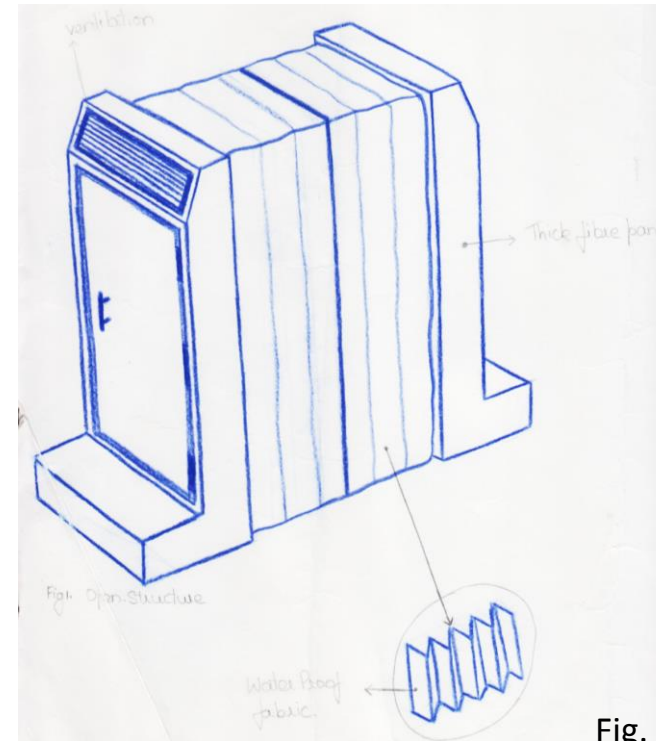
Fig. 5

Modular toilet design was designed in a way that it formed a circular pattern in case 4-5 toilets were placed side by side. It has 3 ventilation ducts 1 on the door and 2 on each of the sides (as shown in fig. 4) it also has an elevated rooftop that provided natural light during the day and fresh air.

Initial ideations (Phase 1)



Parts can be easily assembled and disassembled. Structure is made of glass reinforced plastic (GRP). It is durable, light weight, waterproof and economical. It is easy to clean and maintain. Toilet structure has an extremely sloping roof which prevents the collection of dirt/dry leaves and water during rains. The structure has 3 ventilation duct 1 on its top front and two on its bottom side



This structure is collapsible. It can be closed when not in use, this saves space and makes it easy to transport it. The collapsible portion of the structure is made of water proof fabric that protects against heat and rains and also provides cover. The structure has 1 ventilation duct on its top front

Mockups (phase 1)



Image 26

Mockups (phase 1)



Image 27



Image 28



Image 29

Made using chart paper and mount board. This mock up is trying to depict the structure that is made of wooden panel and is covered with bamboo mat. It has an uplifted roof for ventilation.



Image 30



Image 31



Image 32

Made using mount board. This mockup is trying to depict the structure that is made using a bamboo mat in a circular pattern and also has a sliding door. It has an uplifted roof for ventilation.



Image 33



Image 34



Image 35

Made using styrene and cloth. This mockup is trying to depict structure that is made up bamboo poles that is covered with poly propylene plastic or nylon cloth. This structure had a sloping roof to avoid collection of water and other waste. The roof was uplifted to provide ventilation.

Mockups



Image 37



Image 38



Image 39



Image 40

Made using sun board and mount board. This mockup is trying to depict a Structure that is made of glass reinforced plastic (GRP). It is durable, light weight, waterproof and economical. It is easy to clean and maintain. Toilet structure has an extremely sloping roof which prevents the collection of dirt/dry leaves and water during rains. The structure has 3 ventilation duct 1 on its top front and two on its bottom side.



Image 41



Image 42



Image 43



Image 44

Made using mount board. This mockup is trying to depict a structure that is made of wooden planks at an angle that helps in providing natural light and ventilation. The structure has a sloping roof that which prevents the collection of water and other waste.

Anthropometric Considerations

Stature mean dimension taken (for male) : 1650mm

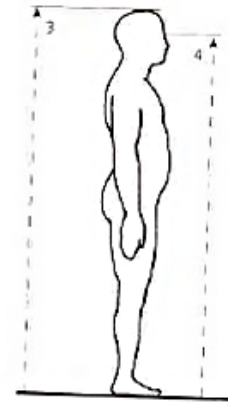


Fig. 8

R.No.	Parameters		Min	Percentiles					Max	Mean	±SD	Ratio
				5th	25th	50th	75th	95th				
1	Weight, Kg.	Male	34	42	48	54	62	76	118	57	11	
		Female	30	35	41	48	55	66	88	49.5	9.9	
		Combined	30	40	47	53	60	74	118	55.2	11.3	
2	Normal standing	Male	1396	1529	1598	1646	1688	1751	1939	1645	74	0.99
		Female	1276	1406	1457	1504	1548	1615	1681	1506	68	0.99
		Combined	1276	1439	1541	1610	1671	1741	1939	1607	98	0.99
3	Stature	Male	1486	1537	1599	1648	1691	1781	1950	1650	70	1
		Female	1288	1429	1478	1517	1567	1632	1711	1523	66	1
		Combined	1288	1465	1555	1619	1673	1771	1950	1614	87	1
4	Eye	Male	1293	1419	1485	1529	1571	1645	1821	1530	68	0.93
		Female	1215	1315	1368	1411	1454	1514	1600	1411	62	0.93
		Combined	1215	1355	1445	1507	1557	1633	1821	1502	84	0.93

Span mean dimension taken (for male) : 1687mm

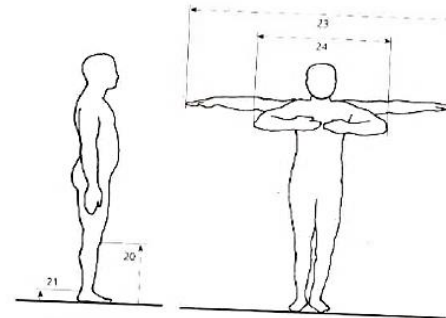


Fig. 9

R.No.	Parameters		Min	Percentiles					Max	Mean	±SD	Ratio
				5th	25th	50th	75th	95th				
20	Mid-patella	Male	346	419	445	464	484	517	607	467	32	0.28
		Female	332	368	400	424	450	479	582	427	42	0.28
		Combined	332	410	443	461	482	516	607	464	34	0.28
21	Lateral malleolus	Male	42	49	54	57	62	70	80	59	6	0.04
		Female	41	42	50	55	61	65	79	56	7	0.04
		Combined	41	48	54	57	62	70	80	59	7	0.04
22	Medial malleolus	Male	54	62	68	73	77	85	96	74	7	0.04
		Female	47	54	64	67	72	84	91	69	8	0.05
		Combined	47	61	67	72	77	85	96	73	7	0.04
23	Span	Male	1392	1549	1634	1684	1739	1829	2040	1687	86	1.03
		Female	1395	1431	1485	1549	1599	1679	1750	1549	75	1.02
		Combined	1392	1479	1583	1659	1724	1809	2040	1655	102	1.02
24	Span akimbo	Male	700	774	831	859	899	959	1165	866	56	0.53
		Female	650	699	749	789	839	889	1199	796	64	0.52
		Combined	650	739	809	849	889	949	1199	850	65	0.53

Anthropometric Considerations

Maximum body breadth (relaxed) mean dimension taken (for male) : 509mm

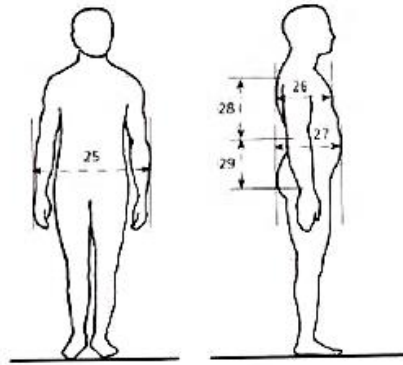


Fig. 10

R.No.	Parameters		Min	Percentiles					Max	Mean	±SD	Ratio
				5th	25th	50th	75th	95th				
25	Maximum body breadth (relaxed)	Male	364	415	459	503	549	619	795	509	68	0.31
		Female	371	391	422	469	519	599	700	477	65	0.31
		Combined	364	405	499	494	539	619	795	502	69	0.31
26	Chest depth	Male	173	186	200	214	231	258	394	219	26	0.13
		Female	159	160	190	207	237	293	370	215	43	0.14
		Combined	159	181	198	214	231	265	394	219	29	0.13
27	Maximum body depth (relaxed)	Male	195	218	250	291	344	409	635	302	63	0.18
		Female	195	205	245	314	369	439	515	315	76	0.21
		Combined	195	212	249	299	349	419	635	305	66	0.19
28	Acromion to olecranon tip length	Male	234	281	299	312	326	356	395	315	22	0.19
		Female	205	263	280	295	316	339	371	299	25	0.2
		Combined	205	272	294	309	324	349	395	311	24	0.19
29	Olecranon to heel length	Male	186	206	228	243	257	289	350	245	25	0.15
		Female	186	183	208	221	241	267	289	226	24	0.15
		Combined	186	194	218	232	249	278	319	235	24	0.15

Vertical upward arm reach, from floor mean dimension taken (for male) : 2101mm

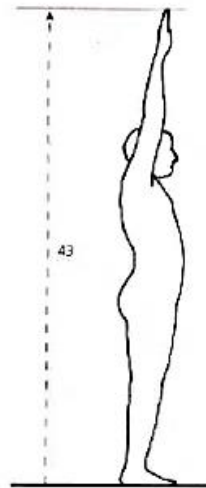


Fig. 11

R.No.	Parameters		Min	Percentiles					Max	Mean	±SD	Ratio
				5th	25th	50th	75th	95th				
43	Vertical upward arm reach, from floor	Male	1830	1929	2029	2109	2159	2259	2410	2101	98	1.28
		Female	1665	1759	1829	1909	1989	2079	2180	1914	102	1.26
		Combined	1665	1799	1959	2059	2139	2229	2410	2050	129	1.28
44	Maximum vertical arm reach, body raised on toe	Male	1960	1999	2119	2189	2254	2359	2520	2188	103	1.33
		Female	1830	1849	1959	2009	2069	2189	2270	2013	95	1.32
		Combined	1830	1939	2059	2159	2229	2339	2520	2145	126	1.33
45	Comfortable vertical upward grasp reach from floor	Male	1643	1744	1863	1945	2027	2146	2370	1950	122	1.21
		Female	nm	nm	nm	nm	nm	nm	nm	nm	nm	nm
		Combined	-	-	-	-	-	-	-	-	-	-

Anthropometric Considerations

Mid-position length mean dimension taken (for male)
: 2101mm

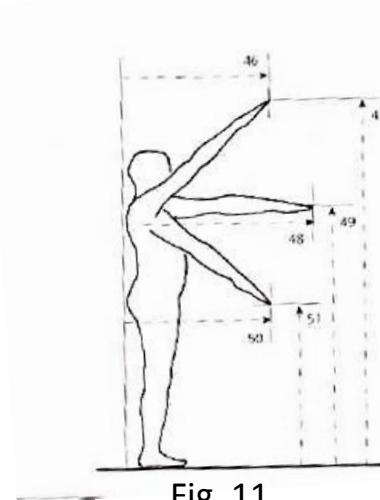


Fig. 11

R.No.	Parameters		Min	Percentiles					Max	Mean	±SD	Ratio
				5th	25th	50th	75th	95th				
46	Upper position length	Male	390	469	559	629	689	799	940	632	100	0.38
		Female	350	399	539	629	689	809	880	613	109	0.4
		Combined	350	459	559	629	689	799	940	628	102	0.39
47	Upper position height	Male	1575	1659	1799	1859	1949	2054	2220	1874	118	1.14
		Female	1290	1519	1659	1759	1849	1949	2060	1747	135	1.14
		Combined	1290	1624	1759	1849	1929	2059	2220	1848	132	1.14
48	Mid position length (Forward arm reach)	Male	589	749	809	849	879	939	1050	847	64	0.51
		Female	600	704	759	799	844	919	980	803	64	0.53
		Combined	589	729	799	839	874	939	1050	837	67	0.52
49	Mid position height	Male	1090	1229	1309	1369	1409	1509	1841	1363	89	0.83
		Female	1070	1139	1209	1279	1329	1439	1540	1278	89	0.83
		Combined	1070	1179	1279	1349	1399	1489	1841	1345	95	0.83
50	Lower position length	Male	340	419	529	599	659	769	1030	597	102	0.36
		Female	495	519	579	659	694	809	850	644	82	0.42
		Combined	340	439	539	609	669	769	1030	607	100	0.38
51	Lower position height	Male	510	659	729	779	839	939	1100	788	89	0.48
		Female	560	619	719	769	819	889	950	765	81	0.5
		Combined	510	649	719	779	839	939	1100	784	88	0.48

Erect squatting height length mean dimension
taken (for male) : 867mm

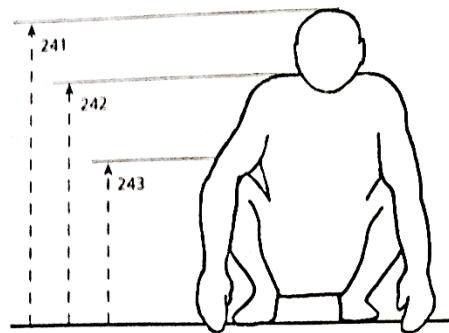


Fig. 12

R.No.	Parameters		Min	Percentiles					Max	Mean	±SD	Ratio
				5th	25th	50th	75th	95th				
240	Normal squatting height	Male	610	729	789	809	845	889	930	812	51	0.5
		Female	655	739	759	784	814	859	880	784	44	0.51
		Combined	610	729	779	804	839	879	930	806	51	0.5
241	Erect squatting height	Male	780	794	839	859	891	959	1057	867	46	0.53
		Female	710	754	799	839	869	919	930	835	48	0.54
		Combined	710	789	829	854	889	949	1057	860	48	0.53
242	Mid shoulder height	Male	465	579	609	639	659	699	795	636	41	0.39
		Female	430	539	579	609	639	679	695	608	48	0.39
		Combined	430	559	606	629	659	699	795	631	44	0.39
243	Right knee height	Male	330	379	414	431	449	484	545	433	33	0.26
		Female	290	309	363	379	409	439	550	382	40	0.25
		Combined	290	349	399	424	449	479	550	423	40	0.26

Anthropometric Considerations

Mid-position length (Forward arm reach)
mean dimension taken (for male)
: 996mm

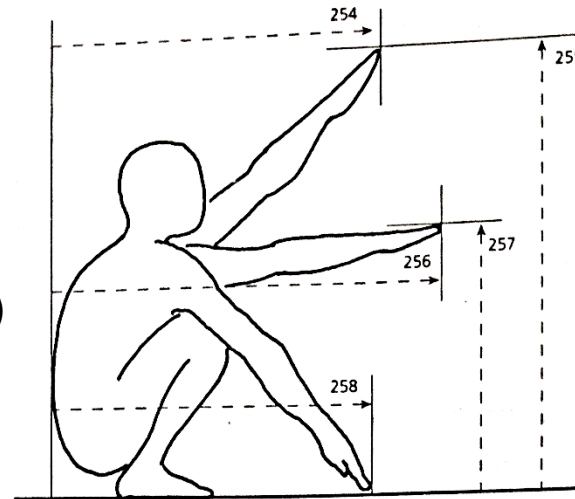


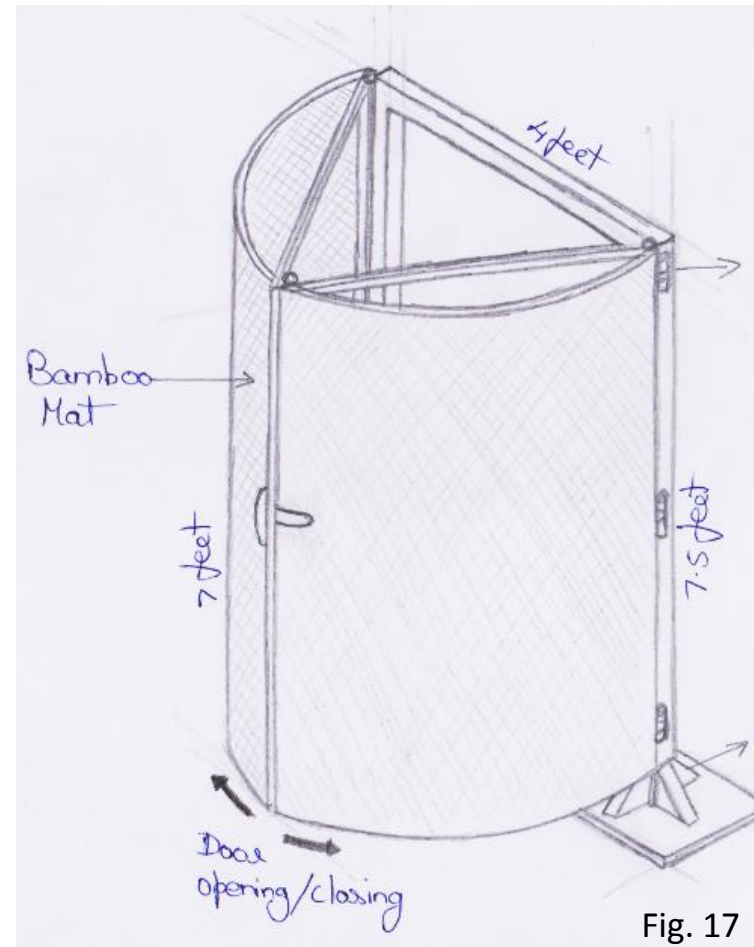
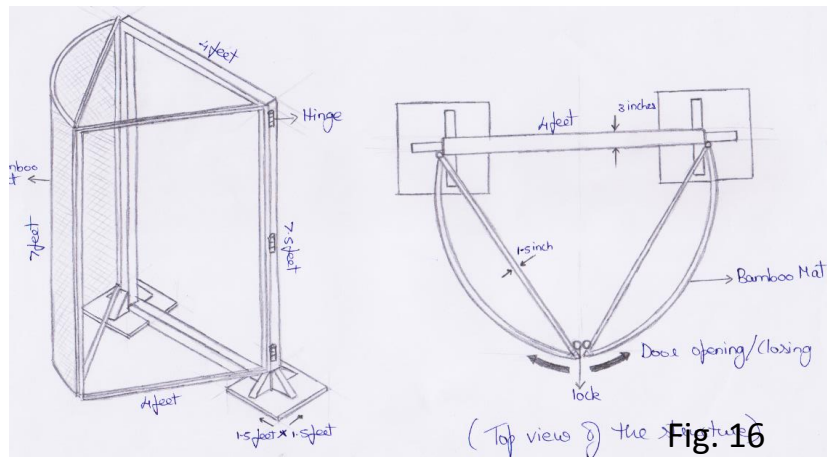
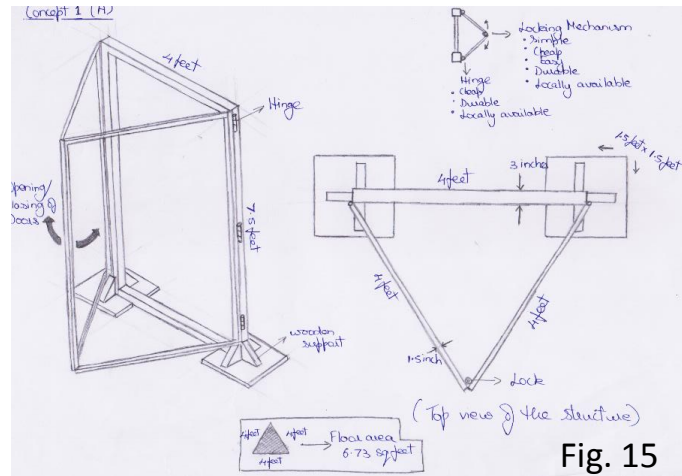
Fig. 14

R.No.	Parameters		Min	Percentiles					Max	Mean	±SD	Ratio
				5th	25th	50th	75th	95th				
254	Upper position length	Male	470	609	749	819	889	979	1090	815	109	0.49
		Female	530	569	749	819	879	979	1030	799	121	0.52
		Combined	470	599	749	819	889	979	1090	812	112	0.5
255	Upper position height	Male	660	839	969	1069	1129	1269	1390	1057	128	0.64
		Female	530	801	949	1029	1099	1259	1270	1013	137	0.66
		Combined	530	839	959	1059	1129	1259	1390	1047	131	0.65
256	Mid position length, Forward arm reach	Male	650	849	949	989	1056	1119	1320	996	84	0.6
		Female	560	839	919	949	1029	1129	1160	965	96	0.63
		Combined	560	839	929	989	1049	1119	1320	989	88	0.61
257	Mid position height	Male	360	414	509	559	589	674	990	554	84	0.34
		Female	330	399	489	539	579	679	960	546	100	0.35
		Combined	330	414	499	549	589	674	990	552	87	0.34
258	Lower position length (touching the floor)	Male	660	729	809	869	929	1029	1150	874	86	0.53
		Female	680	699	799	889	939	979	1070	865	89	0.56
		Combined	660	729	809	869	929	1029	1150	872	86	0.54

Concepts

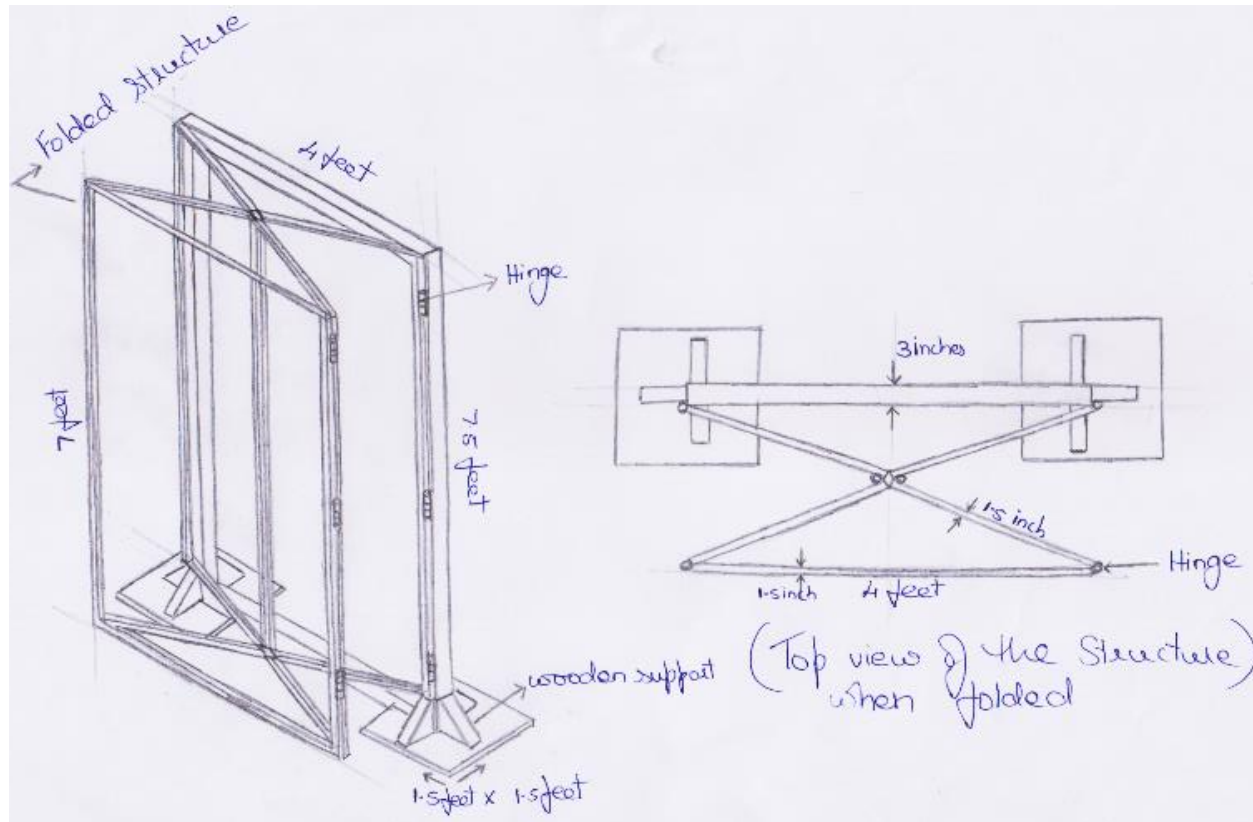
Based on the ideations done, three end to end concepts were made which included the primary features that evolved during the ideation phase, some of the features are ,stability issues, ergonomic considerations, deployability of the structure ,base stand, fixing the structure to the ground, area considerations.

Concepts 1

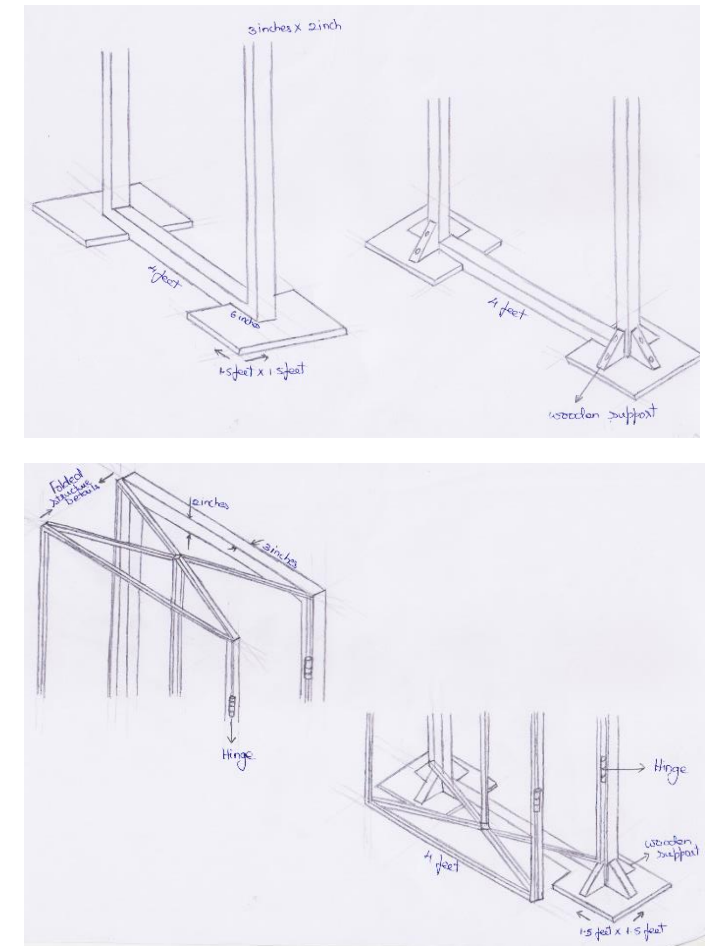


This design has a triangular frame where in ii has 1 main frame and the other 2 act as the door of the structure. It is covered with a bamboo mat in a slightly circular manner to provide more space which makes it convenient for the users to use it. The frame is made of wooden battens and is covered with bamboo mat.

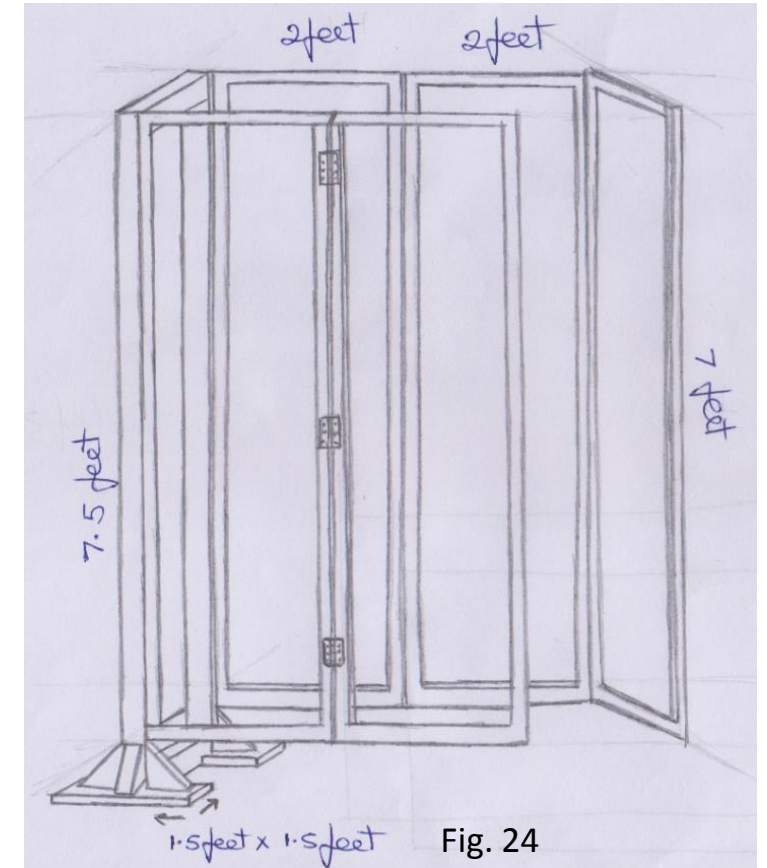
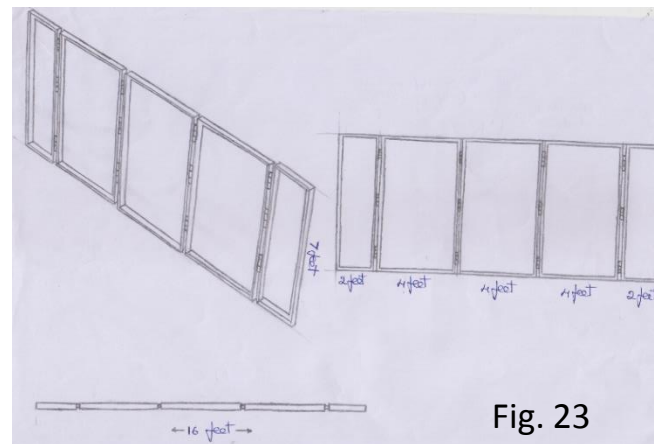
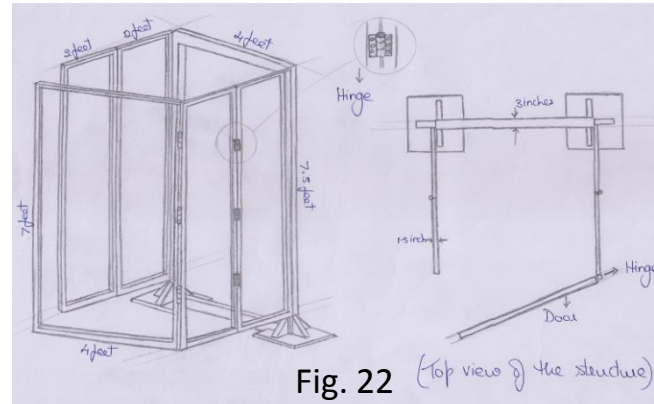
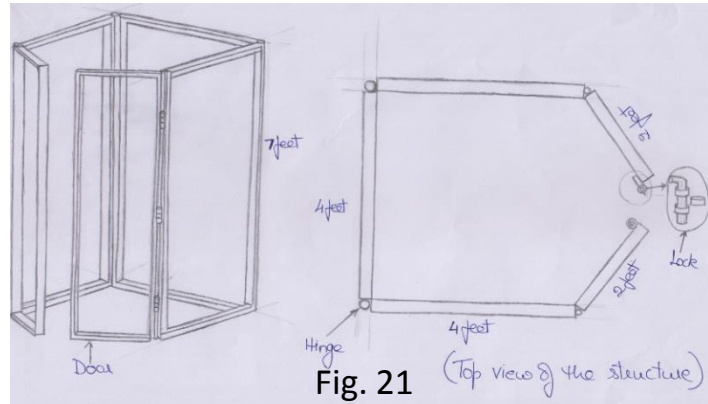
Concepts 2



This design is foldable. It has 1 main frame and 5 others out of which 4 enable it to fold and one acts as the door. The structure can be opened when in use and can be folded and kept when not in use. It saves a lot of space and makes it easy for packaging it.



Concepts 3



This design is the least complicated. It opens up flat and takes the shape of a cuboid structure when folded. It is easy to carry and can be assembled and disassembled whenever needed. Easy to package.

Mockups (phase 2)

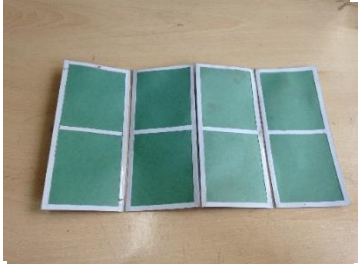


Image 45



Image 46

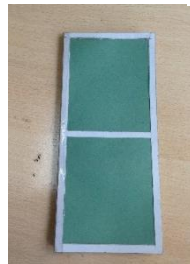


Image 47

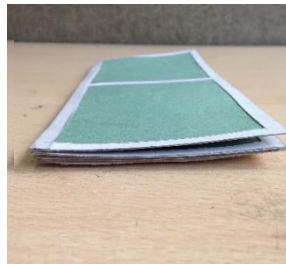


Image 48

Made of mount board. This mock up depicts a Foldable structure that is made up of wooden frames covered with bamboo mats that takes the shape of a cuboid. This structure is easy to package as it can be folded in a door like pattern when not in use. It can be carried from one place to another and is very easy to assemble and disassemble.



Image 49



Image 50



Image 51



Image 52

Made of mount board. This mockup depicts The structure that is made of wooden frames and is covered with bamboo mats that can be opened when in use and can be folded from the center and kept when not in use. it saves a lot of space and makes it easy for packaging it.



Image 53



Image 54



Image 55

Made of chart paper and mount board. This mockup depicts the structure that is made up of bamboo poles covered with bamboo mat. It has a sloping roof that prevents the collection of water and other waste.

Feedback on the project progress

When an evaluation check was done on the project evolution during the stage3, many conclusions were drawn which changed the path of the project significantly, The material used for making the structure was wood and that would not have been available easily in the rural areas with such precision cuts. The whole idea of making the product extremely local and simple was getting lost.

The fixing of the structure as per my design concepts to the ground did not seem feasible. Also the grounding method was too complex and would require industrial process to be cut and fixed.

Changes in the project

- After having a discussion with my guide and other faculty members, the material of the structure was changed from wood to bamboo since I was using bamboo mats in my concepts using bamboo poles instead of wood seemed like a good idea. Also bamboo is easily available in the rural areas, is as strong as wood, provides stability, is extremely low cost, usage of bamboo will make it easy for the users to maintain and build the structure on their own without being dependent on industrial processes.
- The design element was brought in during this phase. Several mat designs were tried to enhance the richness of the structure while making it more stable. Joining details were added in a way that it contributed to the aesthetic value of the structure.

Mockups (Phase 3)

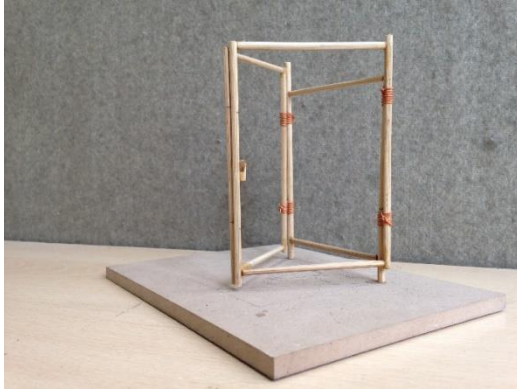


Image 56

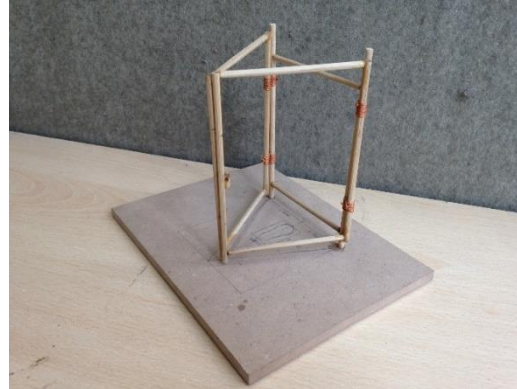


Image 57

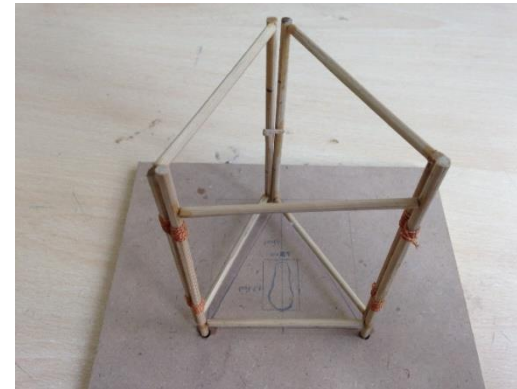


Image 58

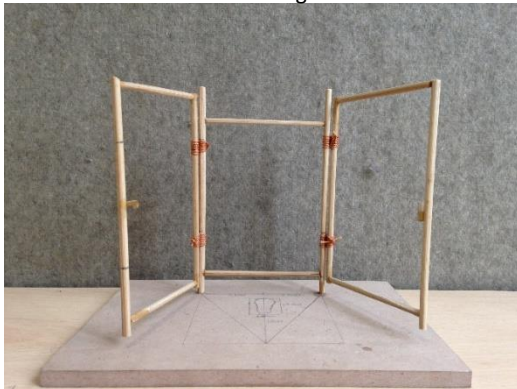


Image 59



Image 60

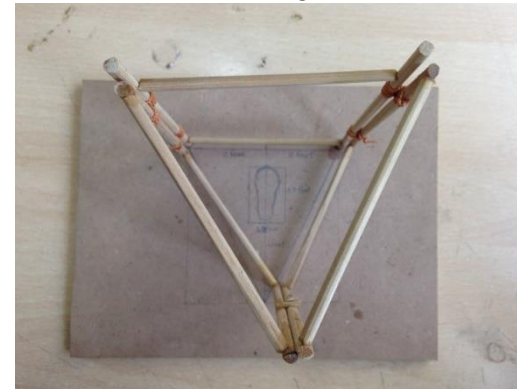


Image 61

Made up of bamboo sticks. This mockup is trying to depict the triangular structure that is made up of bamboo poles hinged together using nylon rope where there is 1 fixed frame and other two frames act like the door.

Mockups



Image 62



Image 63



Image 64



Image 65



Image 66

Made of bamboo sticks. This mockup depicts the joining details of two bamboo poles in the final structure made of bamboo and covered with bamboo mat. The joining detail is extremely simple and is made by alternating the nylon rope on two poles and tying it together. This enable the structure to open when in use and fold and kept when not in use.

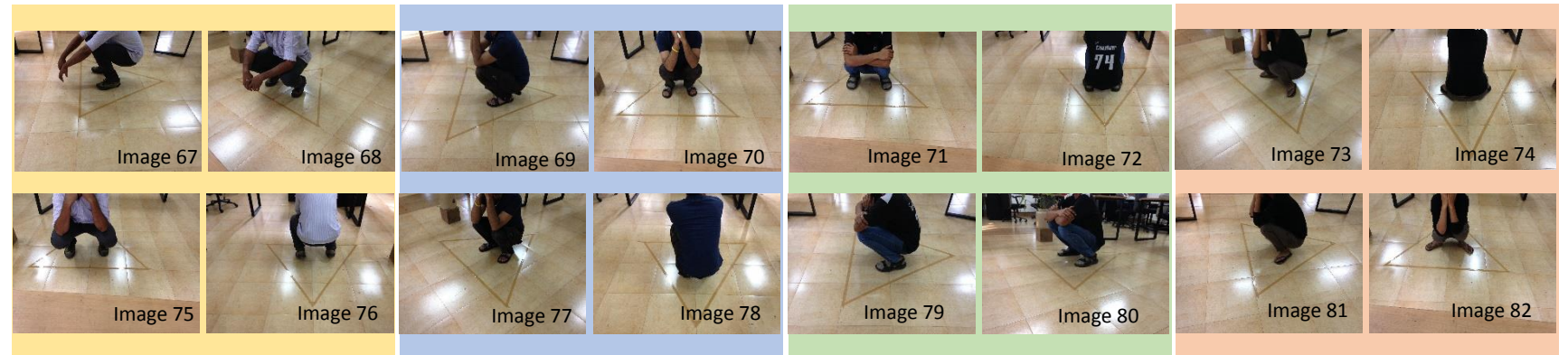
Observation from the user study

After testing the structure layouts a thorough understanding about the product usage was obtained in terms of how the person sits and uses the structure.

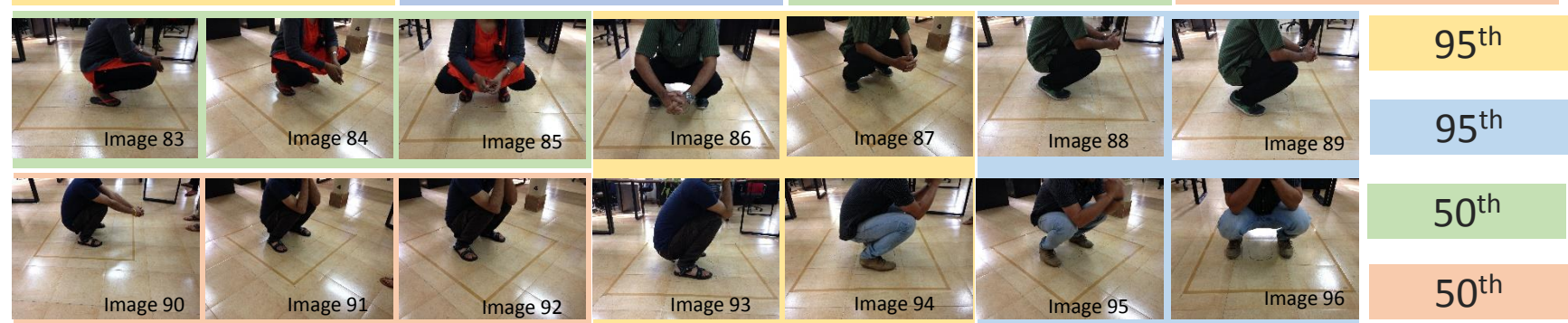
Using the data from photo documentation one could map the areas where the user feels most comfortable in his/her sitting position, this came in handy during the form explorations.

The feed back given by the user during the interaction with the product structure was also immensely useful in refining the product and making it more effective.

Triangular Concept



Square Concept



Final exploration 1

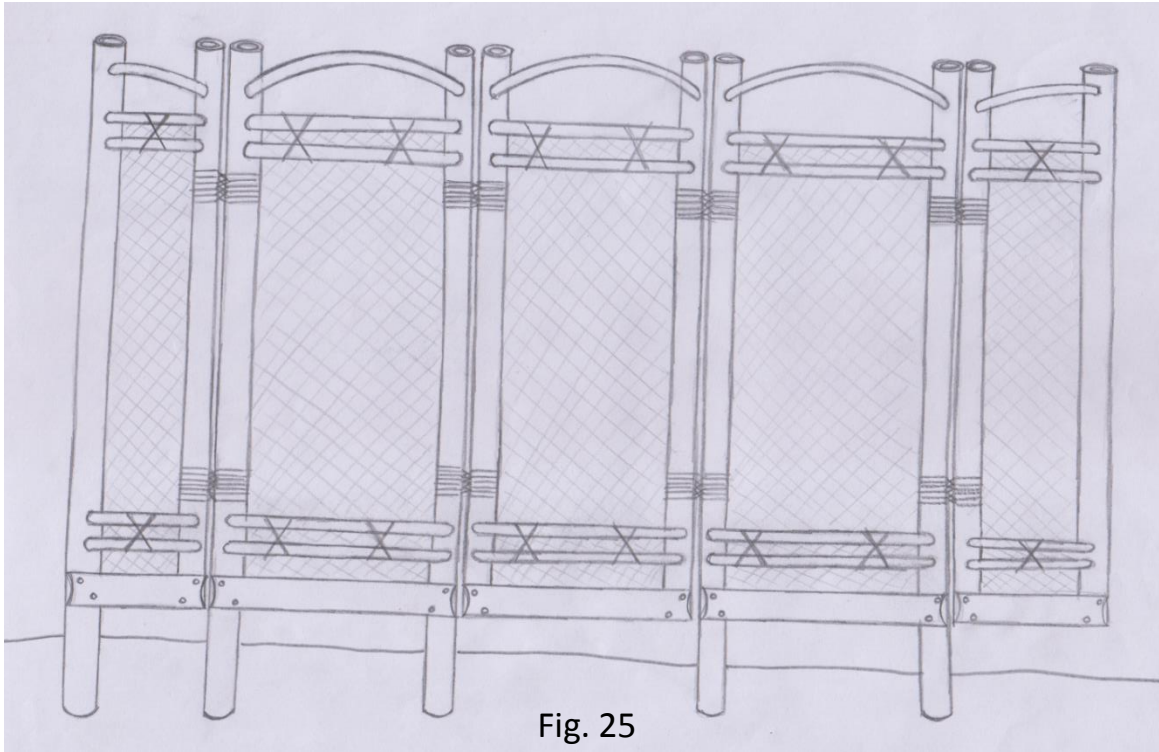
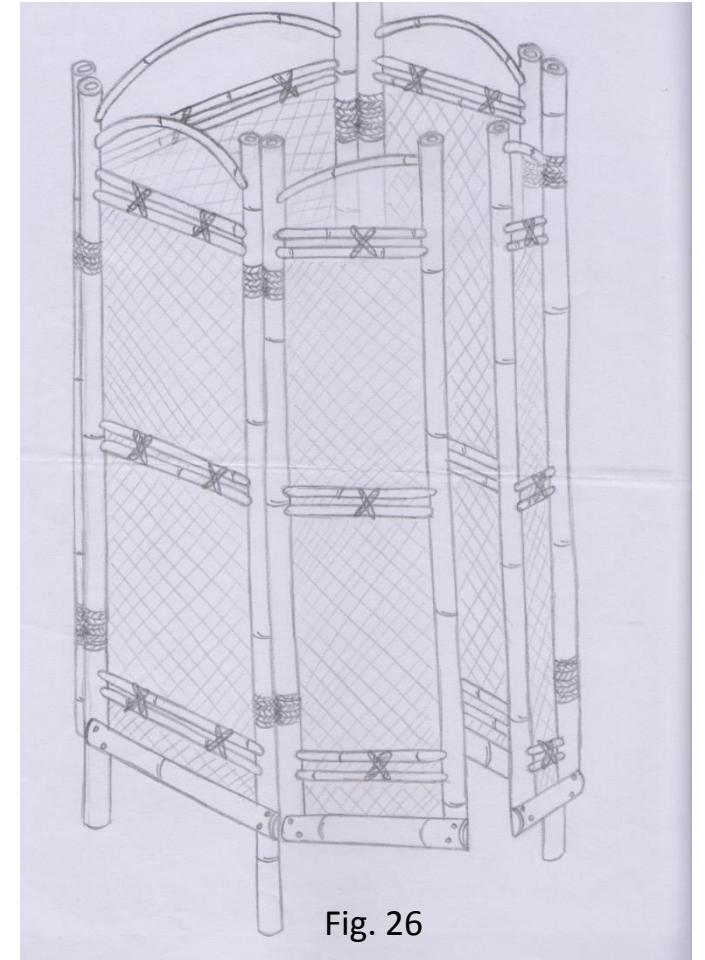


Fig.25 is a structure design when opened completely. It has space for ventilation on the top and bottom of the structure. The structure is covered with bamboo mat and has two bamboo stick on the top and bottom for support which are tied on to the mat in a cross pattern, this joining detail help in adding a design element in the structure.

Fig. 26 is when the structure is folded and is ready to be used.



Final exploration 2

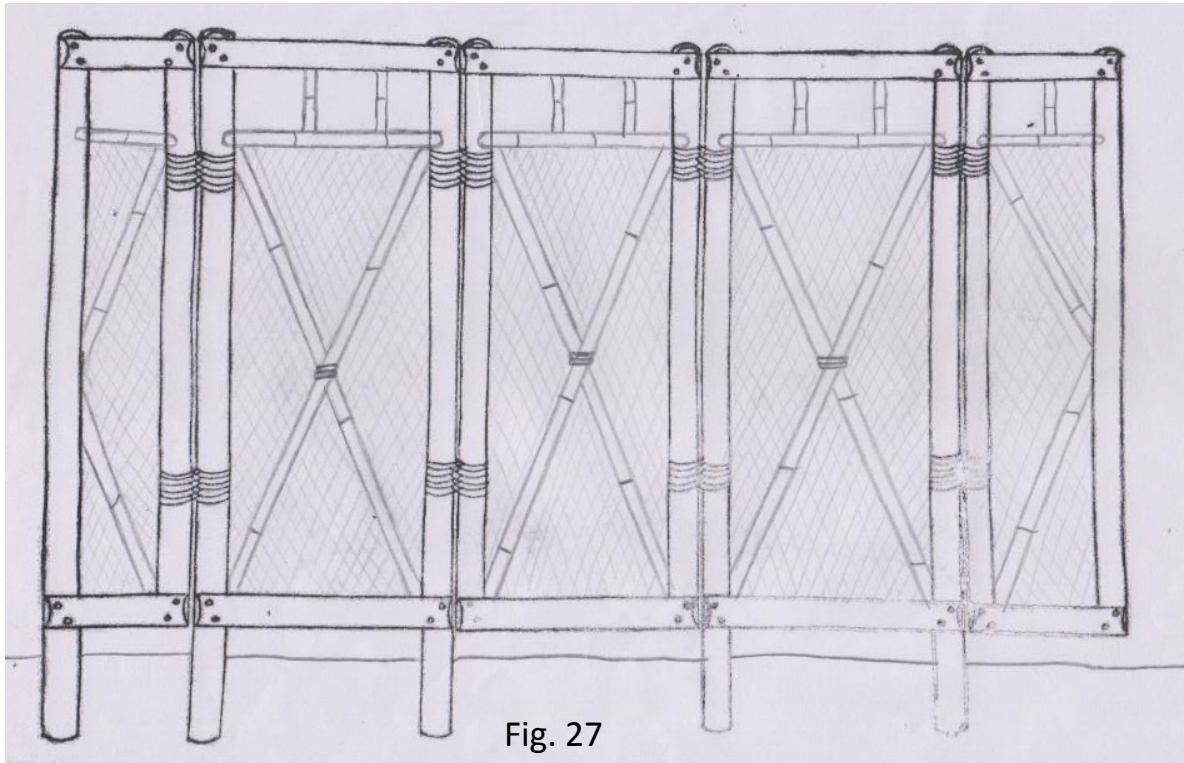


Fig. 27

Fig. 27 is a structure design when opened completely. It has space for ventilation on the top and bottom of the structure. The structure is covered with bamboo mat and has two bamboo stick tied on to the mat in a cross pattern for support. Fig. 28 is when the structure is folded and is ready to be used.

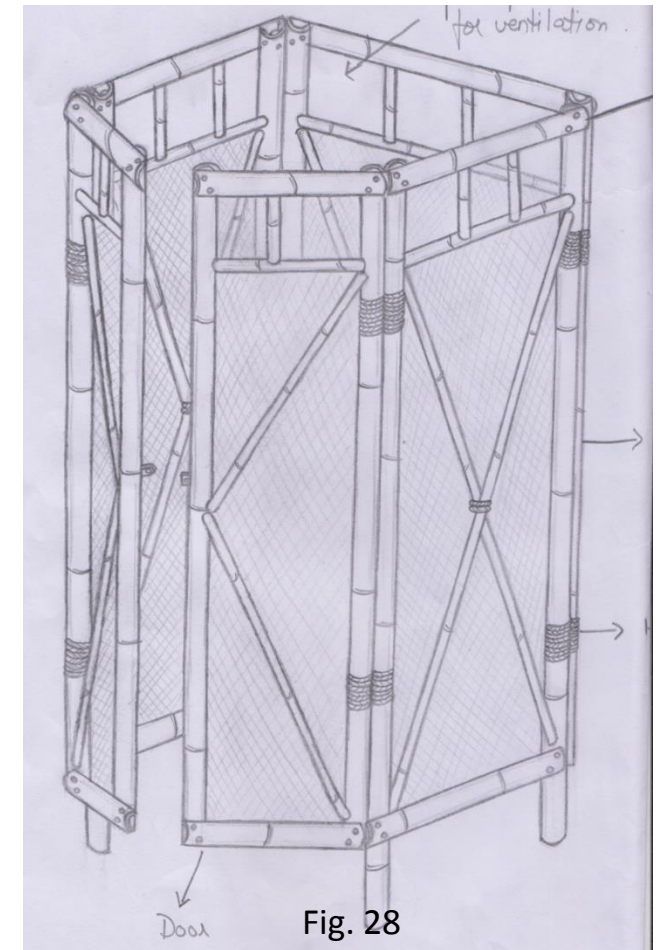


Fig. 28

Final exploration 3

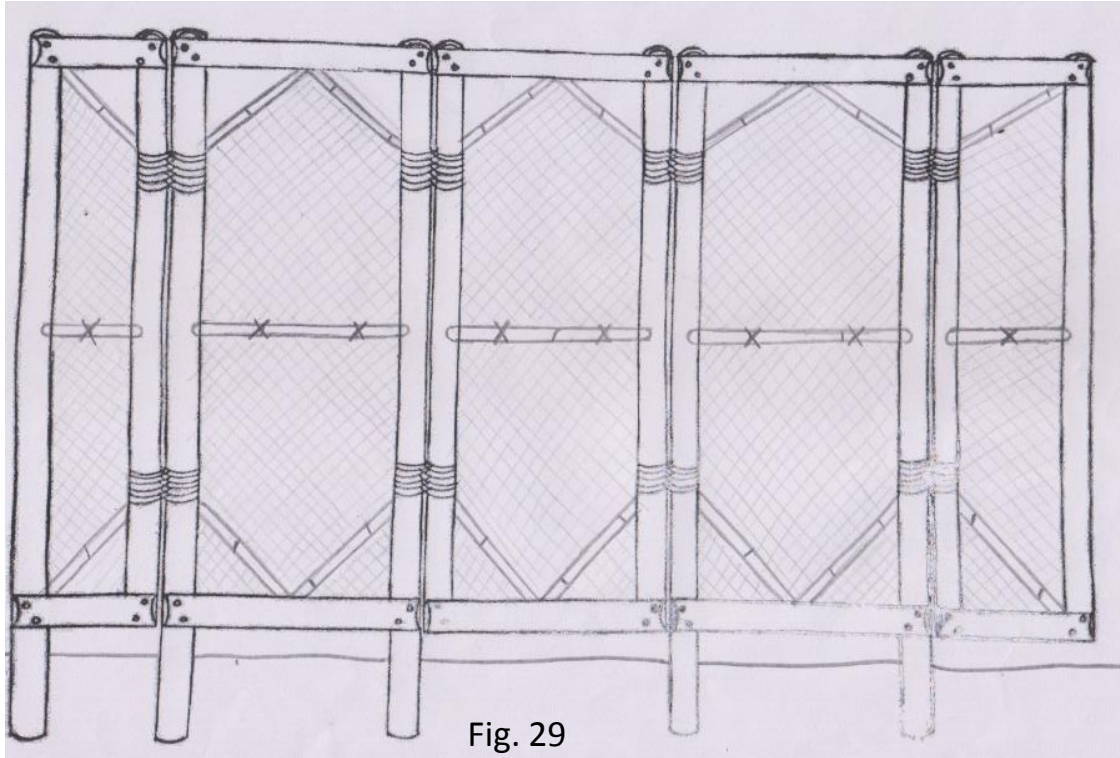


Fig. 29

Fig. 29 is a structure design when opened completely. It has space for ventilation on the top and bottom of the structure.

The structure is covered with bamboo mat and has two bamboo stick tied on to the mat on the top and bottom of the structure in a slant pattern, it also has a bamboo stick tied in the center for support. Fig. 30 is when the structure is folded and is ready to be used.

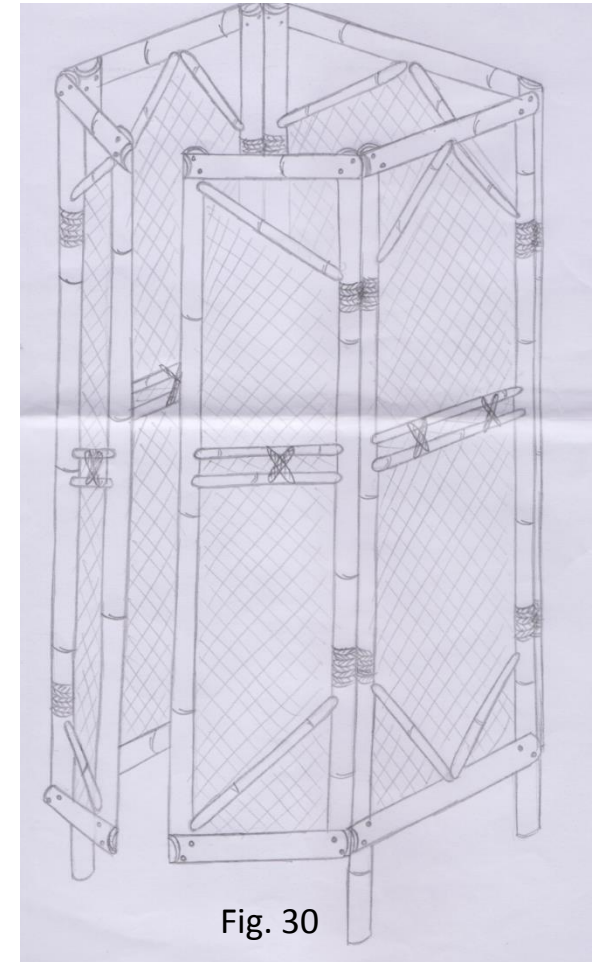


Fig. 30

Final concept

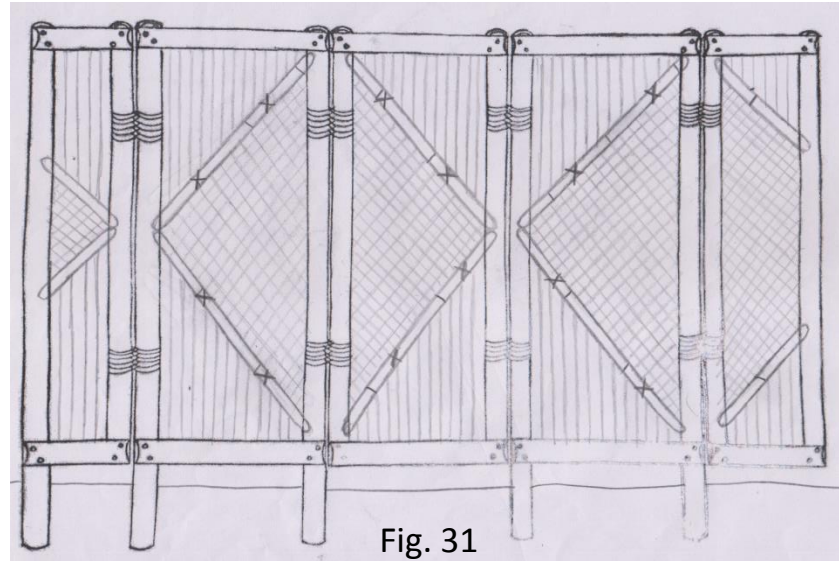
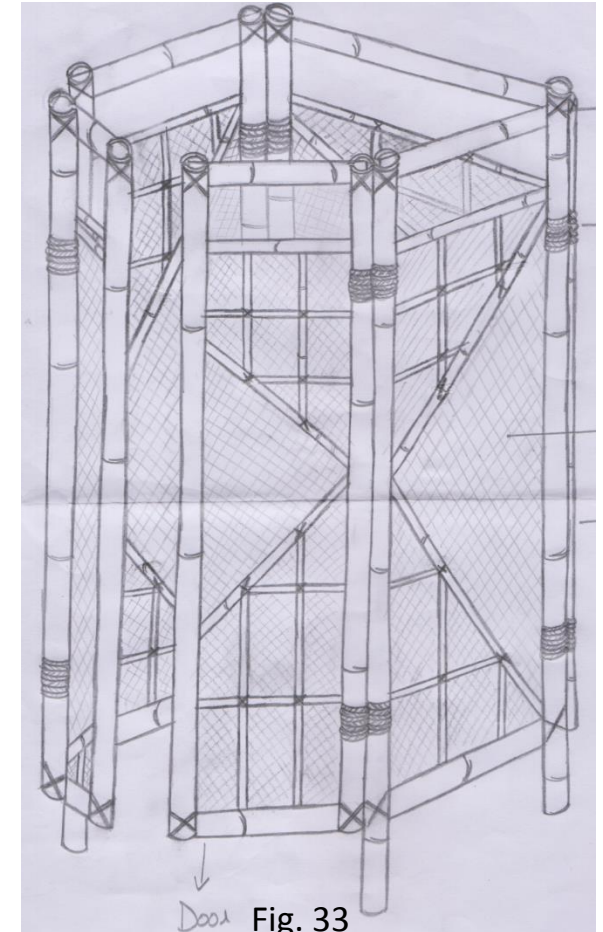
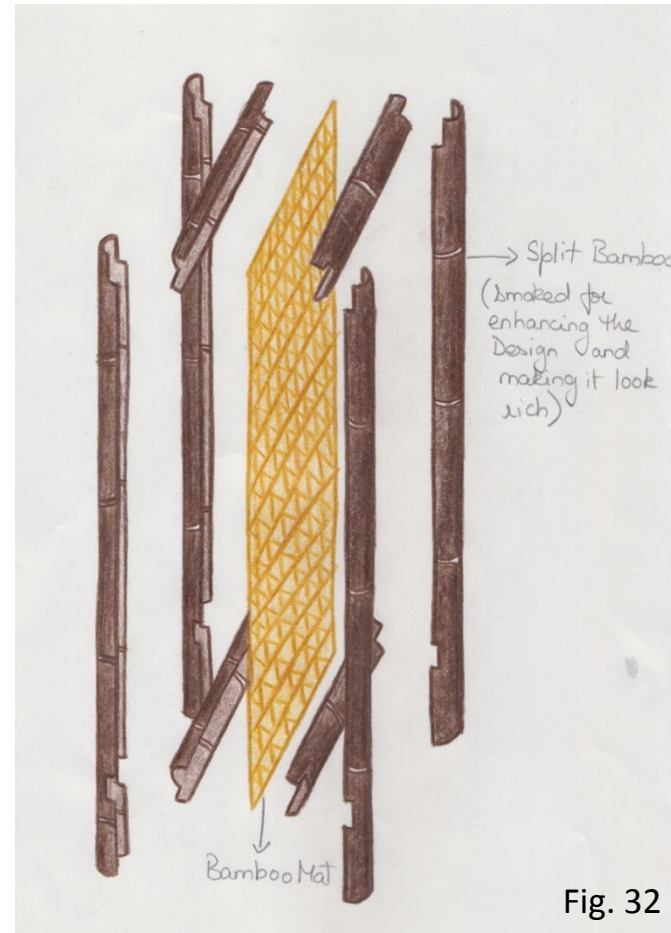


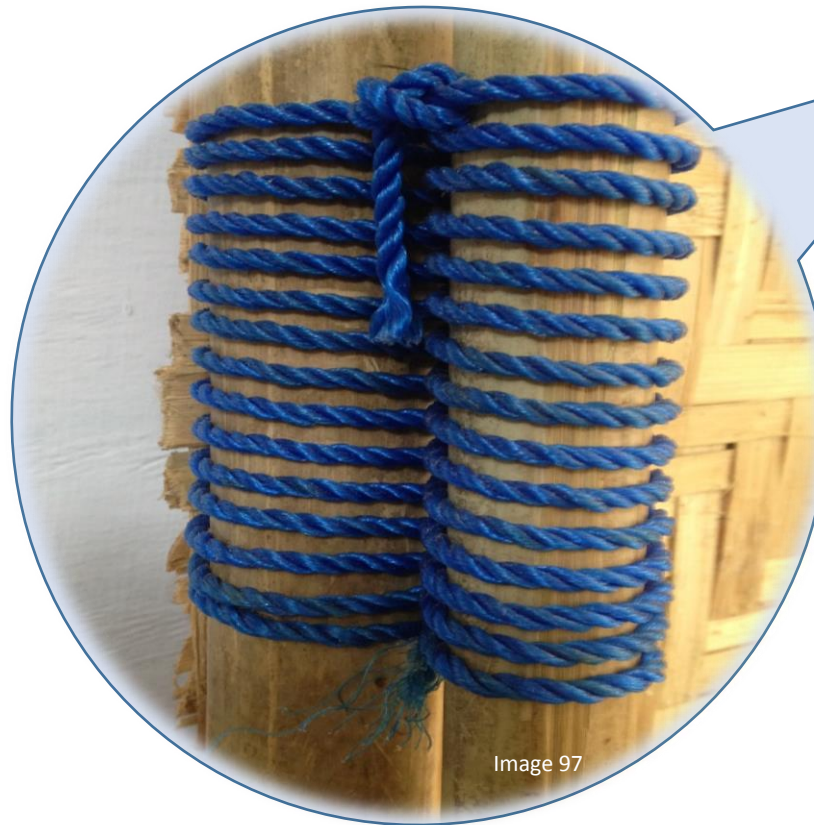
Fig. 31 is a structure design when opened completely. It has space for ventilation on the top and bottom of the structure.

The structure is covered with bamboo mat and has two bamboo stick in the center in a triangular shape that highlights the mat and a criss- cross pattern on the top and bottom for support. They are tied on to the mat in a way, that it helps in adding a design element in the structure. Fig. 32 is the exploded view of the frames of the structure. Fig. 33 is when the structure is folded and is ready to be used.



Hinging details

The frames of the structure are joined together with the help of the hinging detail shown in the Fig. The hinge is tied on to the bamboo poles in an alternate pattern and is made using a nylon rope which provides flexibility, easily available and also is strong enough to carry weight. This hinging technique also enables the entire structure to fold and unfold when in use or not.



Joining details

1. Joining two bamboo poles with each other



Two poles are fixed using a right angle



Two poles are fixed using a L joint



Two poles are fixed using a cross bamboo support with the help of nuts and bolt



Two poles are tied together using cane



Two poles are fixed using bamboo nails.

Joining details

2. Joining the mat to the bamboo
 - By slitting the bamboo poles



Bamboo when slit



Slit bamboos joined together to make the frame



Bamboo mat attached in the slit bamboo frame



Bamboo strips are being attached to the mat to strengthen the structure which also adds to the aesthetic beauty of the structure



Tying the bamboo strips to the mat



Bamboo panel (outside view) ready to be fixed



Final refinement



Inside view of the panel

Joining details

- By splitting the bamboo poles in two halves (**Final structure joining detail**)



Image 112



Image 113



Image 114



Image 115

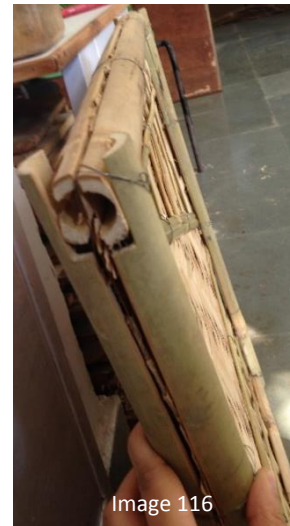


Image 116

In this method bamboo poles are split in two halves then the bamboo mat and the strips are placed in the middle of the two split pieces and are tied together and fixed. This method is easy. Reduces effort and is good from the point of mass production. The joining details add to the aesthetic beauty of the entire structure

Grounding Details

The structure is going to be fixed in a jerry can or a tin box by adding mud and stones in it to make it strong and firm. This can is going to be buried under the ground to make the structure even stronger and to fix it in one place.



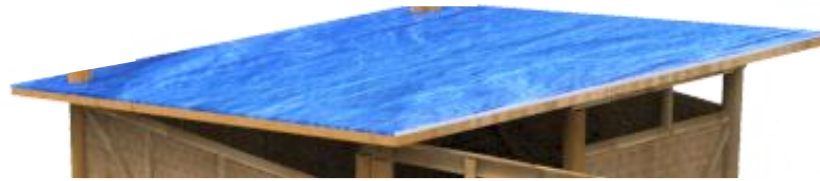
Image 116



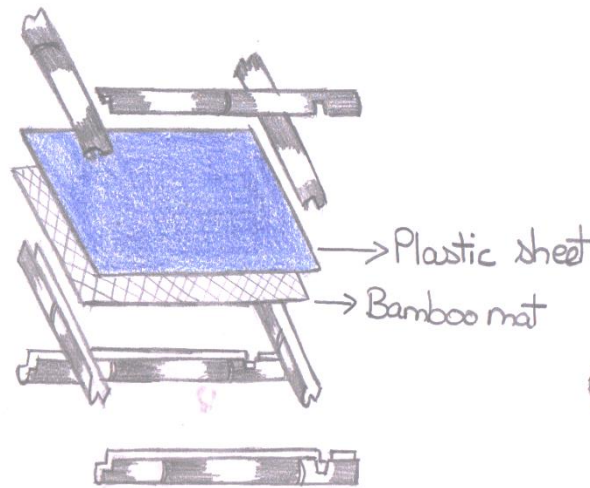
Image 117

Roof Details

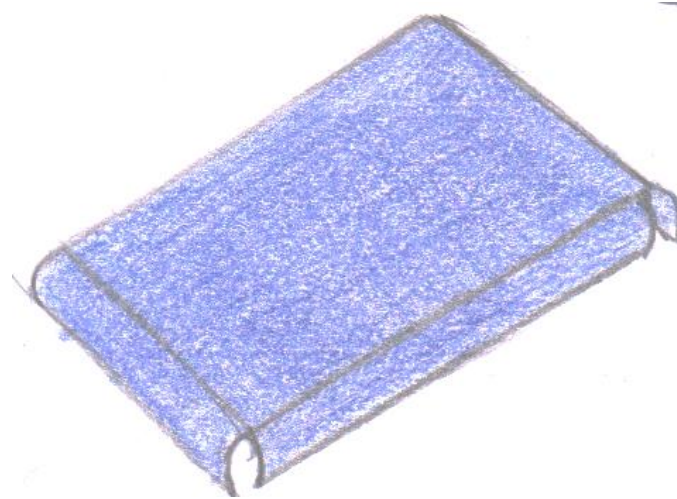
The structure has a roof that is made out of bamboo mat and has a lining of plastic on the top portion to protect it from water in case of rain. The roof is slightly elevated from the structure to provide ventilation. The roof is sloping towards the back to prevent the collection of water and other waste material such as dried leaves. The roof is attached on the top of the structure and is tightly tied on to the structure.



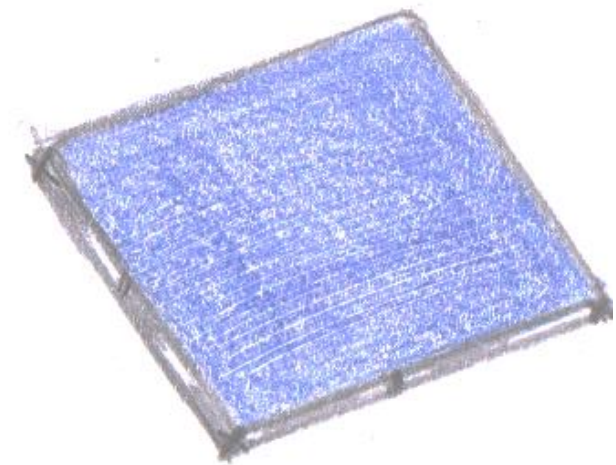
Roof Details



STEP 1- The roof is made in the same manner the bamboo panels were made using split bamboo poles. The mat and the plastic sheet are sandwiched between the split poles.



STEP 2- the plastic is bigger than the mat and is sandwiched from the outer portion covering the bamboo pole to protect the poles from getting spoiled by rain water.



STEP 3- after the mat and the plastic sheet are sandwiched between the bamboo poles they are tied together tightly using a wire. The roof is now ready to be attached to the structure and be used.

Water consideration

- Options to protect the bamboo from water.



Image 118

<http://www.plasticpack.lt/en/packaging-textile-industry>

1) Plastic sheet lining can be put on the inside part of the mat to protect it from the water. Plastic sheet can be sandwiched along with the mat while making the individual frames. Plastic sheets are easily available, easy to use, low cost and have a good life span.



Image 119

<http://www.rongaliinternational.in/products.html>

2) Mixture of cow dung and mud coat can be applied on the structure in order to prevent the structure from getting spoiled with the frequent usage of water. This is the most commonly used method in villages. People put a coat of cow dung and mud mixture on their houses that are made of bamboo to increase its life span. This is an extremely low cost method and can be done easily.

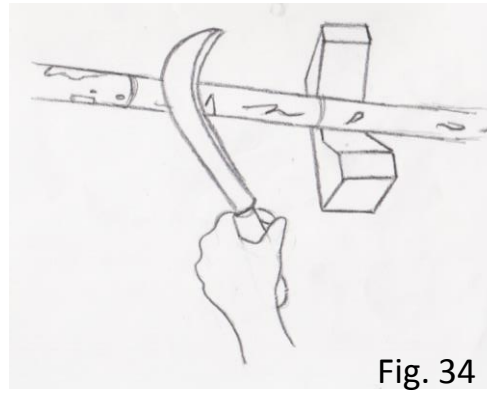
3) Glass composite skin can be applied on to the structure. It makes the structure water proof and strong. It increases the life span of the bamboo. But its an industrial product and won't be easily available in the villages. Also glass composite skin is expensive, hence it is not a suitable material for the village scenario.

<http://www.cleantech.org/magazine/month201108>

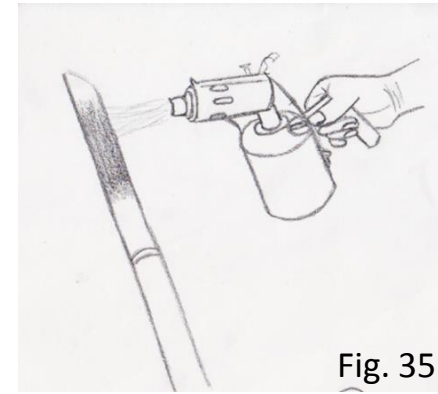
Activity Analysis



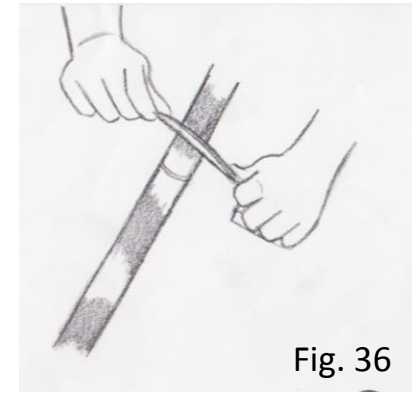
STEP 1- bamboo poles and mat are purchased. There were a few limitations in selecting the bamboo poles- only straight bamboo poles were picked to meet the need of the design, cost of the pole should be low, the pole should be strong enough to provide stability to the structure.



STEP 2- Not all bamboo poles are clean so after selecting and purchasing the poles they are cleaned using a sickle. The poles are kept on a v support so that it can be cleaned properly.



STEP 3- After cleaning the bamboo the pole is burnt using a blow torch. It is burnt to give the poles a texture that helps in enhancing its aesthetic value.



STEP 4- After the bamboo is given the burnt texture, the skin of the bamboo is peeled to give the poles a smooth finish and also to enhance the burnt effect.

Activity Analysis

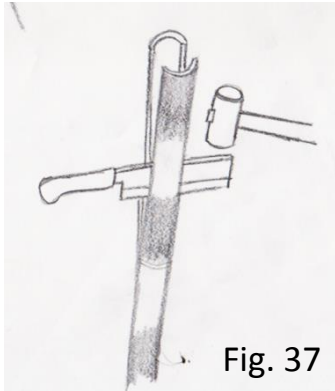


Fig. 37

STEP 5- The pole is split into two halves so that the mat can be fixed.

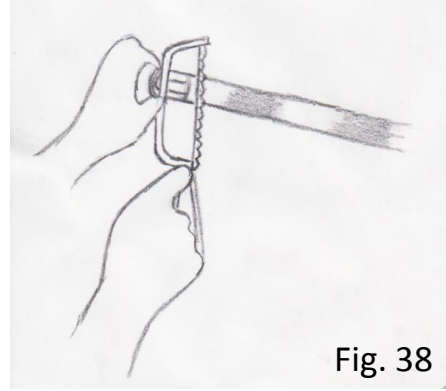


Fig. 38

STEP 6- After splitting the bamboo poles the top of each pole is flattened to make it easy to join to poles together.

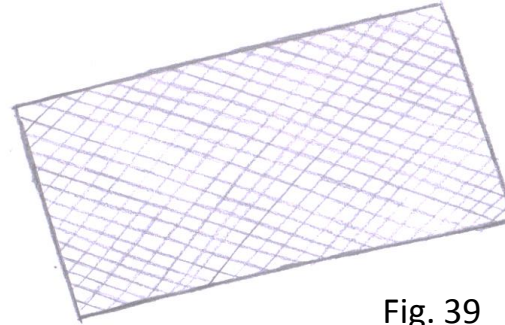


Fig. 39

STEP 7- Ready made bamboo mat of 4*6 feet is used.

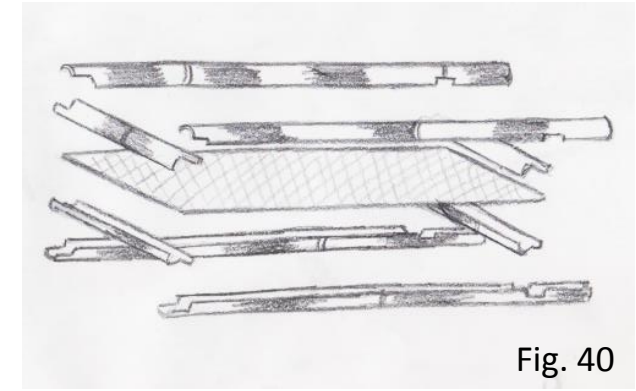


Fig. 40

STEP 8- The mat is sandwiched between the split poles.

Activity Analysis

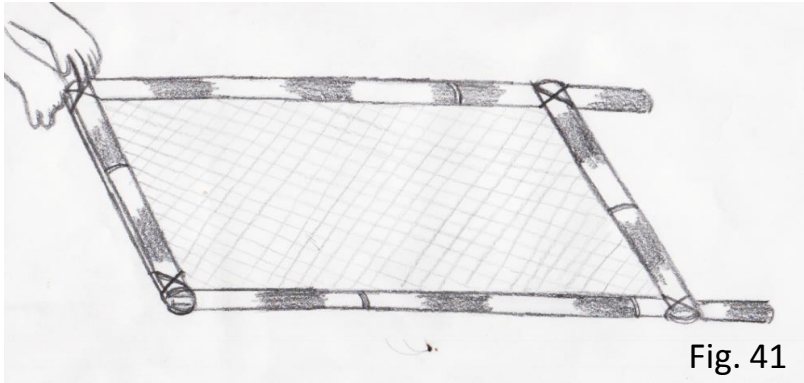


Fig. 41

STEP 9- The mat is properly sandwiched and fixed properly between the poles by tying it using a wire.

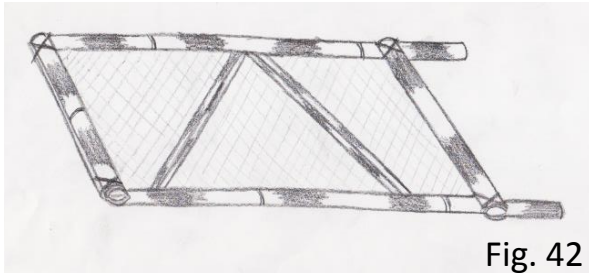


Fig. 42

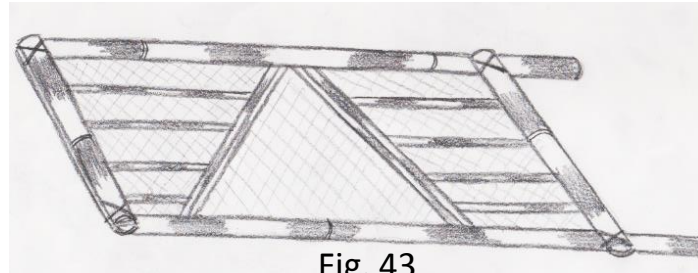


Fig. 43

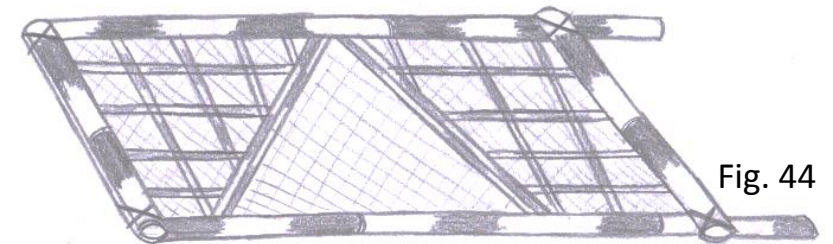


Fig. 44

STEP 10- After the mat is fixed, bamboo strips are attached to give the structure more strength and stability. They are attached between the split poles after the frame is made. They are attached in away that is adds to the richness of the structure.

Activity Analysis

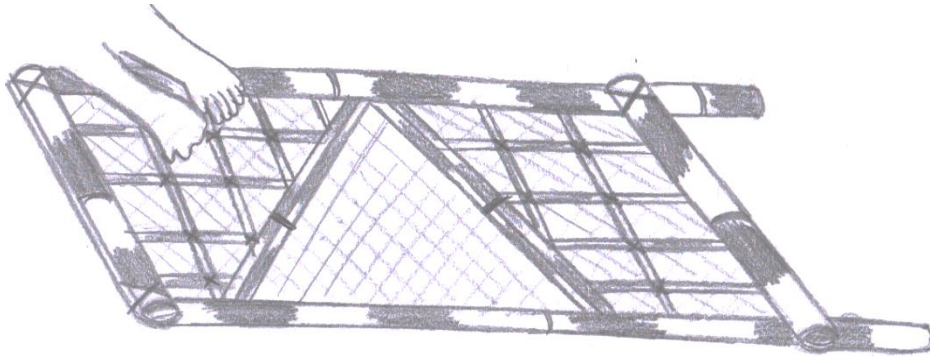


Fig. 45

STEP 11- The strips are fixed onto the mat by tying them up using wire. The joints are checked properly before the frame is ready to be used. All the strips are joined on to the mat in pattern that helps in enhancing the design value of the frame.

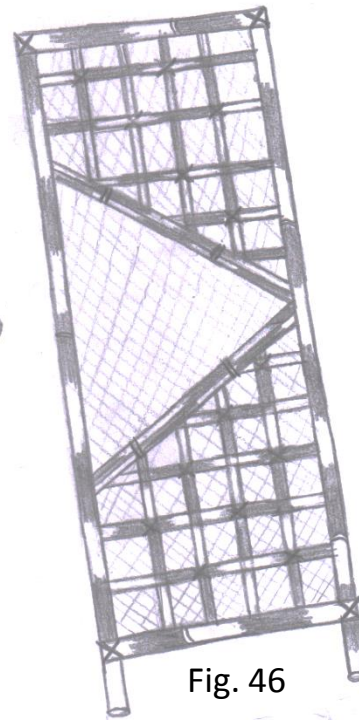


Fig. 46

STEP 13- The frame is now ready to be used.

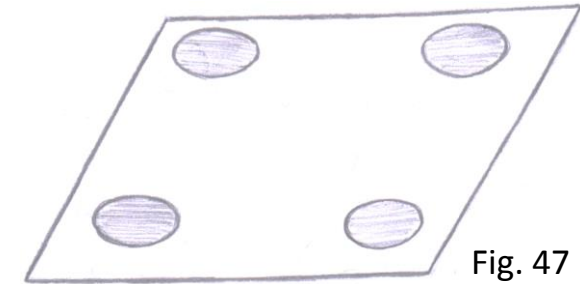


Fig. 47

STEP 14 – After the frame is ready 4 pits are dug into the ground.



Fig. 48

STEP 15 – After the 4 pits are dug into the ground cans or small buckets or pots are placed in the 4 pits for the stability of the structure. A small part of the pot is kept above the ground so that it becomes easy to replace the poles when needed and also to tie them up with plastic covers to protect is from water.

Activity Analysis

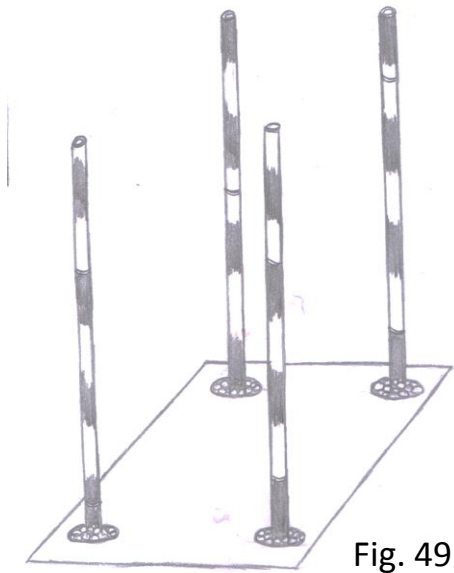


Fig. 49

STEP 16 – After the 4 pits are dug into the ground, 4 bamboo poles are buried into them.

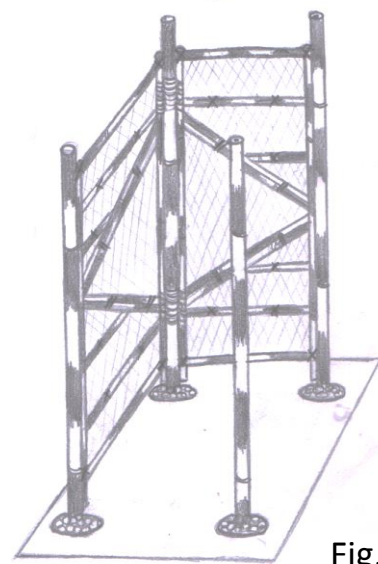


Fig. 50

STEP 17 – After the 4 bamboo pole are buried into the pit, the frames are attached by hinging them to the main poles.

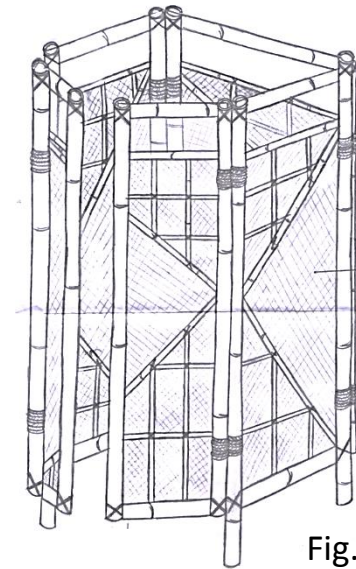


Fig. 51

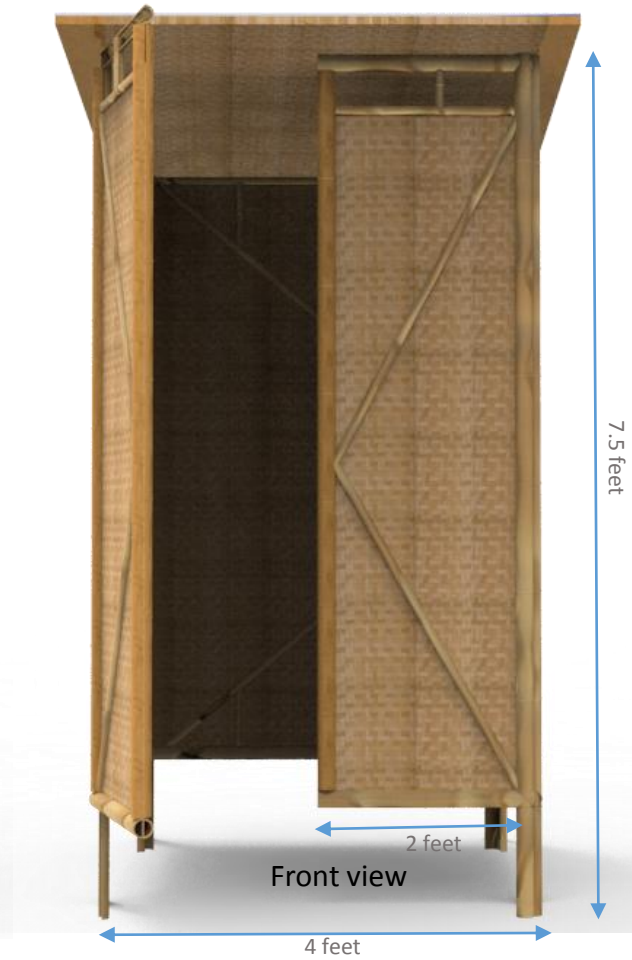
STEP 18 – The structure is full assembled and now ready to be used.



Fig. 52

STEP 19– Final structure.

CAD Modelling



Software Used : Solid works and Keyshot

Structure in the rural scenario



Structure in the rural scenario



Modularity in Structure Design



Modularity is the degree to which a system's components may be separated and recombined. In the structure designed by me modularity in design is possible. Individual frames will be sold so the user can buy as many frames as he wants as per his need and requirement. E.g., a combination of bathroom and toilet can be constructed using 7 frames or a no. of toilets can be constructed side by side in case of common usage by the community.

Stacking and Selling Possibilities of Frames



Since the frames are going to be sold individually they can be stacked and kept. They can be sold individually and the user can purchase as many frames he wants as per his need and requirement. These frames can be sold in the hardware stores, in the local kirana store or in the weekly bazar which happens every week and is a common concept in most villages. One day in a week a market is set in the village so that the villagers buy things that they need from there. E.g. food, clothes, utensils, baskets, footwear, toys, women accessories etc. All the above are the possibilities where the bamboo frames can be sold.

Cost estimation for Prototype

Material	Quantity	Cost (Rs)
Bamboo pole (18')	5	150
Nylon Rope (20')	1	100
GI wire	½ Kg	200
Bamboo mat (4' * 6')	4	280
Steel angles	32	128
Nut bolts	1Kg	80
Kerosene	5 lit	250
Transportation	-	500
Labor cost	-	4000
10 % Overhead cost (Elec. ,Tool, etc.)	-	568
Total		6236

Estimated price of prototype is **6236** /- (including 10% overhead costs)

Cost estimation for one single panel (Mass - Production)

Material	Quantity	Cost (Rs)
Bamboo pole (18')	2	50
Nylon Rope (5')	1	10
GI wire (1/4 Kg)	1	20
Bamboo mat (4' * 6')	1	70
Labor cost (for 2 Labors)		500
Total		650

Estimated price of per Panel is **Rs.650/-** only (including labor cost)

Estimated price of Single structure **Rs.650*4 = 2600/-** only (including labor cost)

Conclusion

The project followed a formal design methodology and proposed a design intervention in a challenging area of providing a Low-cost sanitation structure in the rural areas of India.

Even though many of the preliminary concepts failed, it was possible to refine and look for directions that took the final concept to a substantial level of feasibility. Validation by making the concept work in real life scenario would be the formal way of culminating the project.

Prototype will be presented in the jury.

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