IJRAR.ORG



E-ISSN: 2348-1269, P-ISSN: 2349-5138

INTERNATIONAL JOURNAL OF RESEARCH AND ANALYTICAL REVIEWS (IJRAR) | IJRAR.ORG An International Open Access, Peer-reviewed, Refereed Journal

STUDY ON TRADITIONAL CIRCULAR STRUCTURES AND THERMAL PERFORMANCE

Submitted by Ar.KASTHURI.

Abstract:

This paper seeks to investigate into the to study the Traditional Circular structures in India both religious and habitable space structures and to find out their thermal performance in various regions. To find out the historic background reason behind the circular structures inthose earlier days.

This study proceeds to analyze the detailed field data collected, with a view to identify the indoor thermal environment with respect to outdoor thermal environment in different regions.

There is a regression analysis to obtain information about the thermal environment of different traditional and modern residential buildings with different conditions. To investigated the existing circular earthen buildings that have performed well in seismic activities, and noted their features compared with other earthen buildings.

The paper concludes that, thermal performance of which is better the circular building or other geometrical shape - square ,rectangle shape buildings. To find out the daylight factor inside the building of both Circular and square/rectangular shape building.

Γ

TABLE OF CONTENTS		
CHAPTER NO.	TITLE	Pg.no.
1.	ABSTRACT	i
2.	LIST OF FIGURES	ii
3.	LIST OF TABLE	x
4.	LIST OF SYMBOLS	ix

CHAPTER 1 – INTRODUCTION

1.	1.1 Introduction to circular structures	16
	1.2 Historical / background behind the circular Structures	18
	1.3 The oldest urban plans	19
	1.4 Circle in Architecture	21
	1.5 Middle ages - use of circular plans in Architecture	25

CHAPTER 2

List and Locations of traditional circular structures

	2.1 Traditional Circular temples inTamilnadu	32 J
	2.1.1 Kallalagar Temple @ Madurai	33
2.	2.1.2. Iravatanesvara Temple@Kanchipuram	34
	2.1.3.Sri Sundararaja Perumal Kovil @ Sivagangai	35 2
	2.1.4. Matir Mandir @Pondicherry	36

	2.2 Traditional Circular temples in Kerala	38
	2.3. Traditional Circular Temples in Madhya Pradesh	38
	2.3.1. Sanchi Stupa @ Madhya Pradesh	39
	2.3.2. Chausath Yogini Temple @ Madhya Pradesh	40-42
2.	2.4. Traditional Circular adobe in Gujarat	45
	2.5. Traditional Circular Temple in Rajasthan	51
	Bairat Temple	
	2.6. Nepal Circular Dwelling Units	52
	2.7.Kambalaathu nayakars housing settlement @ Dindigul and Theni	53
CHAPTER - 3 Benefits of circular	Structure	60
CHAPTER - 4 Circular structures	in other areas	64
CHAPTER - 5		67
Earth quake resista	nce of circular adobe buildings	
	5.1.Effect of shape on earthquakeresistance	67
5.	Seismic Capacity Comparison between Square and Circular Plan Adobe Construction	
	5.2 Existing circular shaped adobe houses located in seismic areas to understand their seismic resistance.	71
	5.2.1 Hakka earth buildings in China	72
	5.2.2 Bhunga houses @ Gujarat in India	73

	5.2.3.Yomata houses in Malawi	76
	5.2.4.Building Performances in earthquakes	77
CHAPTER - 6	TEMPERATURE ANALYSIS	
6.1.	Readings - Dry bulb temperature ,wet bulk temperature	82
6.2.	Readings - Roof Surface Temperature	83
6.4	Humidity Analysis	87
6.5	Thermal comfort in vernacular Architecture	88
6.6	Metrological data for chennai Region Temperature ,dew point ,Relative humidity ,wind speed and wind direction	- /89
CHAPTER - 7	,	I
ENERGY SIM	ULATION	
7.1	Daylight simulation	92
7.2	Daylight simulation for Square building	95
7.3	Daylight simulation for Rectangular building	96
7.4	Daylight simulation for Circular building	97
7.5	BIM - Model simulation	97
	7.5.1. Modelling for Circular ShapeStructure in Dindigul District.	98
	7.5.2. Modelling for Square Shape Structure in Dindigul District.	99
	7.5.3. Modelling for Rectangular Shape Structure in Dindigul District.	102
	7.5.4. Modelling for Circular ShapeStructure in Chennai District.	103
	7.5.5. Modelling for Rectangular Shape Structure in Chennai District.	105
	7.5.6. Modelling for Square ShapeStructure in Chennai District.	108
CHAPTER - 8	CONCLUSION	110

LIST OF FIGURES

FIG. NO.	TITLE	PAGENO.
FIG.01	Ancient roman temple Pantheon	18
FIG.02	Some examples of circular contemporry Buildings	18
FIG.03	Neolithic settlements and Town of Biskupin@ Poland	20
FIG.04	Lingang New City (Shanghai),	20
FIG 05:	Palm-cities in Dubai	21
FIG 06	Mesa Verde in Colorado , USA	22
FIG 07	Siberian yurt	22
FIG 08	Wigwam	23
FIG 09	Portable Tipi	23
FIG 10	Eskimo dwelling theigloo	24
FIG 11	Tulou dwelling in China	26
FIG 12	Tulou Chengqilou, Plan of the third storey and cross section through dwellings, internal elevation and staircaseCross section	28
FIG 13	Residential estate with a circular layoutof houses, reminiscent of the tulou	29
FIG 14	Phoenix International Media Center, Beijing, design	30
FIG 15	Aldar headquarters, Abu Dhabi , United Arab Emirates, MZ Architects, 2010	31

LIST OF FIGURES

FIG. NO.	TITLE	PAGE NO.
FIG 16	Map list of circular temples in India.	32
FIG 17	Circular temples in tamilnadu.Srirangam Temple plan,Kallalagr temple at Madurai, Iravataneshwara Temple @Kanchipuram.	32
FIG 18	Garbhagriha at Alagarmalai Temple "Somachandira Vimanam"	33
FIG 19	Overview of IravataneshwaraTemple.	34
FIG 20	Cirular GarbhaGriha at iravataneshwara Temple	35
FIG 21	Cirular GarbhaGriha at sivagangai	:35
FIG 22	Matir mandir @pondicherry	36
FIG 23	Matir mandir meditation hall and top view of matin mandir	37
FIG 24	Sri kovil at koduvilla , kerala	37
		30

FIG 25	Typical srikoil kottayamat kerala	
FIG 26	View of sanchi stupa at madhya pradesh	39
FIG 27	Plan of mounument on the hill at sanchi	40
FIG 28	Chausath yogini temple @Madhya pradesh	40
FIG 29	Hill top chausath yogini temple	42
FIG 30	Chausath yogini temple @ Hirapur	42
FIG .31	Plan of chausath yogini temple	44
FIG 32	Map of kutch , Gujarat	45
FIG 33	Elevation of bhunga houses	46
FIG 34	Wind flow in circular house in Gujarat	47
FIG35	Cross section of bhunga house	47
FIG 36.	Plan along with elevation of bunga house	48
FIG 37	Interior view of bunga house	49
FIG 38.	Step by step procedure of Roof construction of Bhuga House	49
FIG . 39	Plan of bhunga house	50
FIG . 40	Ceiling of bunga house and view of bungahouse	50

FIG. NO.	TITLE	PAGE NO.
FIG 41.	View of bairat of temple	51
FIG 42	Plan of bairat temple	51

Fig.43	Nepal mud dwelling	52
Fig.44	Double storey mud circular dwellings	52
Fig 45	Map show the location of kambalathu nayakars houses @dindigul	54
Fig 46	Map show the location of kambalathu nayakars houses @Dindigul	55
Fig 47	Map show the location of kambalathu nayakars houses @ Salem	55
FIG 48	Temple Circular Temple @salem	56
Fig . 49	Thombarai - to store grains ,ceilling plan of circular structures	57
Fig . 50	Map showing the location of kambalathu nayakars houses @ Theni	58
Fig 51.	View of kambalathu nayakars houses @ Theni	58
Fig 52	Left picture :Circular mud house Right picture:Concrete Structure	59

FIG. NO.	TITLE	PAGE NO.
IG.53	Airflow in circular buildings	61
ig 54	Roof- Construction Elements	62
Fig . 55	shows the spaceefficiency of circular adobe houses.	64
Fig . 56	Apple Park @ California	64
Fig : 57	Camden Roundhouse	65

Fig :58	Beijing, the Temple of65 Heaven
Fig : 59	Rondavels Farm 66 Residence
Fig : 60	Rondavel dwelling with67 small gable building at the back, on the seasonal winter farm of the Bosman family
Fig .61	69 Kutch Mud Houses
Fig : 62	Circular building in the69 small area and interconnected points in a round home
Fig. 63	circular building with 70 courtyads
Fig.64	71 Circular building without courtyads
Fig.65	Circular building - Indian71 parliment and chausath yogini temple
Fig .66	Tulou earthen building -72 Hakka house in china
Fig.67	Circular building During74 construction
Fig .68	Bhunga houses 75 earthquake resistant.
Fig.69	Typical House of Yomata76 House in Malawai

FIG. NO.	TITLE	PAGE NO.
Fig.70	Square and circular specimens configuration and dimensions for stilt test -for seismic	78
Fig.71	Circular and square block first crack appearing and square block when tilted further	78
Fig.72	Tilting the circular block	79

	and first crack	
	appearing and when	
	tilted further	
Fig. 73	Chart shows the 82	
	temperature(dry bulb)	
	reading	
Fig. 74	Chart shows the 83	
0	temperature(wet bulb)	
Fig. 76	Cross section of circular84	
	Roof Structure temple	
	@salem	
	Chart shows the Wall85	
Fig. 77	surface Temperature	
	Reading	
Fig. 78	Plan of the Kambalathu86	
	nayakars house with	
	dimensions	
	Chart shows the 87	
Fig. 79	Humidity Reading	
Fig. 80	Stablized mud block 88	
	circular structure	
	Metrological data for 89-90	
Fig. 81	chennai Region	
	Honey bee - output 91	
Fig. 82	visualization	
Fig. 83	Grid based visualizing the 92	
	annual day light	
	simulation for square	
	structure	
Fig. 84	Grasshopper script 93	
Fig. 85	Grid based visualizing the 95	
<u> </u>	annual day light	
	simulation for	
	rectangular structure	
L		

Fig. 86	Grid based visualizing the96 annual day light simulation for circulr structure
Fig. 87	Simulation Modelling99 Result for circular shape structure in dindigul region

Fig. 88	Simulation Modelling102 Result Square Shape Structure in Dindigul District.
Fig. 89	Simulation Modelling105 Result Circular Shape Structure in Chennai District.
Fig. 90	Simulation Modelling108 Result Rectangular Shape Structure in Chennai District
Fig. 91	Simulation Modelling110 Result Square Shape Structure in Chennai District.

LIST OF TABLES

TABLE NO.	TITLE	PAGE NO.
Table no . 01	Table shows the temperature(dry bulb) indoor and outdoor temperature reading @dindigul	82
Table no . 02	Table shows the temperature(wet bulb)indoor and outdoor temperature reading @dindigul	83
Table no . 03	Table shows the Roof surtace above and below temperature reading @dindigul	84
Table no . 04	Table shows the wall surtaceindoorandoutdooroutdoortemperaturereading@ dindigul	86

Table no . 05	87 Table shows the humidity indoor and outdoor temperature reading @dindigul
Table no. 06	Comparative analysis of the Energy cost for the112 Square,Circular,Rectagular structures

AIM

To find out the hidden historic background of the circular shaped structures.

This study is to make an aware about circular structures that has been constructed in those earlier days.

To do an comparative study on other structures with circular structures in respect to architecture.

To investigate and understand circular shaped structures are resistance to natural disaster -To gain knowledge about the circularform.

To study about the about the climatic factors and thermal performances of circular shaped structures.

OBJECTIVES:

This study is about to investigate and gaining knowledge about circular structures includes Historic /background,Form,material,traditional methods of construction techniques that has been followed and their Seismic and their thermal performance.

1. INDTRODUCTION

Circular urban systems and structures were shaped by several factors:

- 1. safety,
- 2. community demand,
- 3. worship,
- 4. expression of emotions and
- 5. experience of decision makers and builders.

At times when the defence of people and their possessions was a frequent necessity it was a ring of walls or circular rampart or tower on a plan of a circle that were used.

Logics of this solution can be easily proved by simple equations.

When mathematics imbued with magic or religion, and became a tool of shaping architecture, use of a ring was symbolic, and often used in sacredurban layouts and architecture.

Circle, as the most perfect of figures was appreciated by the people of powerof all periods up to now.

First theoretical urban plans developed either from circular focal building or implemented circle or ring in shaping the whole layout.

In the era of rationalism theorists of that time saw the opportunity to organize functional zones in concentric way. Recent decades unveiled new phenomena: circular projects in urban and architectural scale.

The circle as a symbol and a practical geometric figure .Solar deities were worshipped in prehistoric and ancient times, across different parts of the world and in different ways - under a ubiquitous symbol - the circle.

The circle is present in all cultures, religions and belief systems as a magical and symbolic sign.

Who says you have to live in a rectangular house?

In fact, a quick look at the history of architecture tells us that many indigenous cultures relied on circular dwellings. And lately, they are

undergoing a resurgence with tiny home enthusiasts looking to maximize space or green homeowners seeking energy efficient options.

The oldest forms of indigenous shelter were often round. Think of the Southwest American hogan, the Mongolian yurt, the North American teepee and the Greek temenos. Why did our ancestors choose to build round?

Because an ovoid shape — like that of eggs, the earth, tree trunks and stones — is what they saw reflected in their natural environment and, asusual, Mother Nature knows best.

What makes round architecture so appealing?

Round homes stand up to extreme weather. Their curved roofs make them wind resistant—less susceptible to high-velocity gusts lifting up the roof and tilting up the house. As wind can flow around the circular structure, instead of getting hung up around the angles, these homes are particularly **resistant tohurricanes and tornados**.

And with dozens of interconnecting points forming a strong support system, circular houses have extra structural strength and flexibility. This is the reason you will see round architecture adapt to heavy snowfall and earthquakes.

And in heat?

The rounded walls help with that as well. With 20% less exterior wall space, heating and cooling bills are automatically reduced and good natural airflowmeans comfort, even in desert climates.

But in terms of function and efficiency, a look at indigenous architecture tells the true tale of why round homes reign supreme. Whether a nomadic Yurt, Navajo Hogan, or Arctic igloo, cultures have built round structures for specificreasons.

Circular houses use inherently fewer materials than their square counterparts, an attractive option when resources were scarce and extra labor meant expending precious energy.

"Square plan provided more space efficient space than a circular plan. Because it is hard to be managed and it is difficult to put furniture into around shape." (Mazlin 2008)

"Circular plan would be more difficult to build. But could be very interesting to live in." (Demand Media Inc. 2009)

1.2 HISTORY OF CIRCULAR BUILDINGS

In 1963, Deaton would go on to construct his only residential piece of architecture—a circular residence 16th century, influenced by the shapes of Greek and Roman temples



FIG.01

ANCIENT ROMAN TEMPLE PANTHEON

Architect Andrea Palladio became obsessed with the circle as the perfect form. Pulling from concepts by Vitruvius, Palladio's rounded architecture was thought to exemplify balance and harmony and has long influenced architects.





FIG.02 SOME EXAMPLES OF CIRCULAR CONTEMPORARY BUILDINGS

Buddhist Mandala

Where the circle symbolises the sky, transcendence and infinity, and the square represents the inner self, that which is associated with man and earth.

The **Chinese JinYang** from the Book of Changes symbolises the interplay of opposites of the same the **Indian swastika** (circular, different from the one commonly known), is a symbol which refers to the **cult of the sun; it meanslife, fertility and good fortune.**

The symmetric pagan Celtic cross (the sun cross) was combined with a circle. Dancing was the oldest for of worship of the powers of nature and gods, practiced by societies of old.

A ring of dancers would form naturally; prayer would be said in a circle. The places for such rituals would be circular, which, amongst others, determined the shape of the Greek theatre orchestra.

The gathered formed into a ring to preform rites around a fire; thus the circlehad both a symbolic as well as a practical dimension.

Many temples and places of worship across different cultures were constructed on a circular footprint

- the British Stonehenge,
- the Polish Seven Sisters (Siedem Sióstr),
- the Buddhist stupas.
- Burial sites plans of prominent society members and priests were oftenbased on a circle.

People were living under the canopy of the sky night and day, and to depict it was a creative act from the boundaries of the realm of magic. The faces of the Sun and the Moon were constantly watched. **The horizon was a circle.**

The cyclicity of day and night, the seasons of the year, the lives of plants and humans are also perceivable as continuous, which is reflected in beliefs. **Maya, Inca and Aztec calendars** are also circular.

Apart from the magical and religious significance, since the dawn of society builders used the shape of a circle in construction as it was easy to mark outon site with simple tools: two stakes and some rope, string or even a strip of leather.

Settlements and town outlines were circle like, **most primitive shelters wereon a circular footprint** - regardless of the materials they were made out of or the climate zone.

The oldest urban plans

For defence reasons, the oldest Neolithic settlements were oval.



FIG.03 Neolithic settlements and Town of Biskupin@ POLAND

Biskupin, a historical monument from the 8th century B.C. is an example of this, where, despite the use of log constriction which imposes orthogonal plans for houses and the street layout, the defences are in an oval shape.

Plains, without natural defensive land forms, predestined just such a shape for early settlement defences, defensive towers and fortified towns.

A similar circular shape was also assumed by the *kraal* and the *boma*, African enclosures, to protect livestock against predators at night.

Subsequent centuries brought with them city planning problems associated with the industrial era. This primarily boiled down to ensuring respectable living conditions for their residents.

A number of concepts based on concentric, circular layouts were coinedduring that time. Amongst others, those include **Ebenezer Howard's** correct town development principle published in 1898 and revised in subsequent decades.



FIG.04 Kibbutz for 250 families 1940, arch. Samuel Bickels,

FIG.04 Lingang New City (Shanghai), gmp Architekten von Gerkan, Margand Partner

The essence of this concept was to provide the residents with access to opengreen areas, to reduce smoke pollution in cities and improve living and working conditions. The central city and satellite cities; separated by open, green areas - that was to be the new face of urbanisation. The factor which dictated the concentric rings of functional zones in satellite cities was access to the basic town functions and correct proper access isochrones.

The twentieth and twenty first centuries did not bring about solutions to town planning. The phenomenon of increasing fragmentation of its structure in modern local plans and urban sprawl generated, amongest others, by individual car communication, turned the architects' attention to the role of the society in shaping town space and the fact that it is there for the people.



FIG 05: Palm-cities in Dubai

The concept of a society as the main medium for urban values, on an emotional and ideological level was fulfilled by concentric layouts of a number of kibbutzim, which the Jewish architects, to a large extent students of Bauhaus, erected in the forties and later, for the settlers in then Palestine, and subsequently the Jews running away from the Holocaust.

Similar idea was expressed in Lingang New City, an extension to Shanghai. As the city grows towards the East Chinese Sea, a new centre is going to take over inhabitants working in the area of the new port and industrial zones.

For palm-cities in Dubai, that is of paramount importance when it comes to promoting the given location. The urban layout not identified from the pavement and road levels, creates its brand.

<u>1.4</u> <u>The circle in architecture</u>

Mesa Verde in Colorado (USA), is an Ancestral Puebloans Indian settlement dating back to the 12th century, built on an inaccessible rock shelf, under a rock overhang. Similar to Pueblo Boniti of the same tribe, built using brick and stone



FIG 06

Mesa Verde in Colorado, USA

It comprises irregular, rectangular like and rounded buildings and round, ritual buildings. These interiors, the *kivas*, were used for male ritual dances.

Just like other cultures, Indians were seeking to mirror the cosmos which surrounded them using the circular plan.

A circular, regular footprint reflected the function (dancing in a circle) and also the technical capabilities (marking out a ring and chiselling out a cylindrical "wall").

As Marta Tobolczyk points out in her book "**The Birth of Architecture**", rounded building forms, as well as corners, came about not as much as a result of primitive technology, **but were primarily a reflection of organic forms** which the builders encountered and which they considered to be more beautiful, and probably, friendlier.

The second, more primitive form of a home, used to this day is the tent. Excavations and partially surviving dwellings aside, it is the **Siberian yurt**which has the longest tradition and history as well as most modifications associated with the way people lived under its roof.

The steppes, where nomadic peoples created and improved this portable home for large families, are the playground for strong winds. The dome-like, squat and symmetric shape of the yurt



FIG 07 Siberian yurt

stands up to them tremendously. Small trees growing in the tundra and widely available animal skins are used to construct it. Cylindrical homes with pointed roofs dominate in Sahel, these are spacious huts made out of branches and covered with hay.

The North American Plains Indians created two types of home-tents: the wigwam for permanent dwelling and the portable tipi - both of a circular footprint.



FIG 08 wigwam

Their structures constitute frames made out of thin trunks, radically different in each case: dome like for the wigwam and conical for the tipi.

Both forms stemmed from experience and stood up to the elements in their own particular ways: the wigwam in a similar fashion to the yurt, whereas theslender tipi "sliced" the wind.



FIG 09 PORTABLE TIPI

As in the Plains there was a shortage substantial wood construction materials, a structure using tree saplings led to two solutions:

a cone, tied at the top and covered by animal skins, and a similar structure, where the uppermost parts of the saplings are bend creating a dome.

The winter **dwelling of Eskimo** families, the igloo, has also a circular plan. Built out of blocks of hard snow, it was covered by a dome, with additional snow piled on top, protected the inhabitants against hurricane winds from theNorth.



FIG 10

Eskimo dwelling the igloo,

The practical side of the above solutions, despite the use of various kinds of materials remains similar:

it is relatively easy to erect a structure on a circular plan both out of wooden elements and a dome out of snow blocks. A regular, symmetrical layout provide uniform resistance against variable wind loads.

The circular interior allows various functional arrangements: both hierarchicaland equal.

A similar structural concept is in use in stone homes, which one may comeacross in various parts of Europe.

Erected on a circular footprint, they are shaped like slender domes; can be found in Turkey (Izmir region), in Italy (Apulia), in France and in Croatia.

The availability of slate and shortage of timber resulted in the use of the localbuilding materials in the simplest manner possible.

1.5 Middle ages - use of circular plans in Architecture

In the Middle Ages, in the present day China homes were built on a circular layout for the same reasons as in Europe.

The Chinese called them *tulou,* which means "earthen structure", despite some of them being erected out of stone.

Tulou is a **dwelling for an entire family**, typical for the mountainous areas in the south and west of the Fujian province.

Often a temple stood at the centre of a complex, a family sanctuary, sometimes accompanied by other buildings.

The circumference wall had three to four storeys of living quarters on theinside.





TULOU DWELLING IN CHINA



FIG 11

Tulou <u>Chengqilou</u>

Due to climate, storage space was often located on the top storeys. These structures were erected from the 12th century all the way through to the start of the 20th century.

They were expanded by adding external rings of walls with further dwellings resulting in a very characteristic, concentric layout.

Access to the interior of a *tulou* was through a single guarded gate

The Hakka people, one of the ethnic groups which erected these structures, used the properties of a circular plan to establish a non-hierarchical society.

All families had same size rooms, and one family owned vertically stackedpremises from the ground floor all the way to the roof.

Large families had a few such sections. This was connected with the necessity to defend the structures by shooting gun posts near the top.

A circular or oval layout made it possible to establish a hierarchy or acommunity on equal terms.

Tulou Chenggilou



Tulou Chengqilou, plan of the third storey and cross section through dwellings, internal elevation and staircase cross section

Figure 3, 4. Tulou Chengqilou, plan of the third storey and cross section through dwellings, internal elevation and staircase cross section²⁵





FIG 12

Figure 3, 4. Tulou Chengqilou, plan of the third storey and cross section through dwellings, internal elevation and staircase cross section²⁵

Contemporary Architecture

Modern concepts are constantly exploring urban planning ideas of the days gone by. They enforce the establishment of communities in today's cramped cities. One of these is the concept of a residential estate with a circular layout of houses, reminiscent of the tulou. Such a complex was built in 2008 in China.

The Tulou Collective Housing, is a complex of affordable housing coined by URBANUS Architecture & Design Inc. as well as architects Xiaodu Liu and Yan Meng, located in Guangzhou, Guangdong province. In 2010 this projectwon the Aga Khan Award.







FIG 13 Residential estate with a circular layout of houses, reminiscent of thetulou

The outer ring of the contemporary *tulou* is made out of a seven storey circular block, with a four storey apartment block in its centre.

Both structures are linked by footbridges at different levels with the roof of the lowest building a terrace for all residents.

The ground and first floors contain commercial units accessible from passageways and ground floor courtyards.

Amongst others, establishing a residential community means the apartments are available only for those who do not have a car and as a rule will spend more of their time in the vicinity of their homes.

This experimental estate originally invokes *tulou* housing tradition in its mostinteresting form.

Slightly earlier, in 2001, a university halls of residence was created in Copenhagen, with a shape similar to the Chinese *tulou*.



FIG 14 Phoenix International Media Center, Beijing, design



FIG 15 Aldar headquarters, Abu Dhabi , United Arab Emirates, MZArchitects, 2010



Over the last decades, it wasn't only the pro-social factors which affected theuse of central solutions. New aesthetic experiences, which today millions of people are part of and which entail air travel and use of a Google Map type applications. In such a situation, an urban planning layout, with a defined, recognizable shape is not only a source of information about the location of a building, but also a source of aesthetic experiences.



FIG 15 The National Centre for the Performing Arts, arch. Paul Andreu, 2007

CHAPTER 2.

Location of circular Structures in India CHAUSATH YOGINI TEMPLE (((ARAICALEMANA) Sanchi Stupa 3rd century Huts of Kutch PRATHIHARA House hist)- Mahar CHAUSATH YOGINI TEMPLE -11th cent HAUSATH n (name Gajaprishta(eleph ant rump)sty 8TH Cetury KANCHEEPURAM The Entire garbhagriha is constructed with stone,, bricks and lateraite blocks. KANCHEEPURAM TANJORE

List and Locations of traditional circular structures

FIG 16

MAP LIST OF CIRCULAR TEMLES IN INDIA

2.1 TRADITIONAL CIRCULAR TEMPLES IN TAMILNADU



FIG 17 CIRULAR TEMPLES IN TAMILNADU- SRIRANGAM TEMPLE PLAN, KALLALAGAR TEMPLE AT MADURAI, IRAVATANESHWARA TEMPLE@KANCHIPURAM.

2.1.1 ALAGARMALAI- Kalalagar Temple @ Madurai

This is one of the ancient temples of South India and has figured in Parilpadal, which is generally accepted to be written about 2000 years ago Once upon a time Yama, the Lord of Death, while going on pilgrimage to all the sacred places on earth, was attracted by the beautiful panoramic view ofthis place and immediately sat down for meditation.

By that time Yama noticed that a halo of the moor was spreading around the place and he ordered Viswakarma, the divine (architect) to construct a Vimanam at that spot in the shape of a moon Viswakarma executed it in no time. The Viswakarma built this beautiful temple with the three tiers "Somachandira Vimanam" which stands for its architectural features.

The temple is very ancient made by the famous architect Viswakarma.

The people used to visit Alagarmalai to offer their first produced grains to the Temple.The archaeological studies about the Epigraphy found in this area proves that the temple is in existence from B.C.2-3 century (Muthu Pichai 2005).



FIG 18 Garbhagriha at Alagarmalai Temple "Somachandira Vimanam"

The hill was once a safe refuge for the **jain monks in 1 B.C,t**he presence of pirami script carved on stones proved the presence of jains in this area

(Muthukonar.s 1973). **Nakkirar**, the Tamil poet has composed several popular poems about this diety.As the place itself suggests, the temple is

dedicated to alagar who is popularly known as Sundrarajar. It is said that it attracted the pilgrims even in the early days of the **Sangam age**. (Mohan.R2004).

This is one of the ancient temples of South India and has figured in **Parilpadal**, which is generally accepted to be written about 2000 years ago(Balasubramanian.P.et al 2004).The Famous **Silapadikaram** too, that belongs to the **3rd Century**, **points out to this temple as a Vishnu temple**.

2.1.2. Iravatanesvara temple @Kanchipuram



FIG 19 OVERVIEW OF IRAVATANESHWARA TEMPLE

The **Iravatanesvara temple** is located in the temple town

of Kanchipuram in Tamil Nadu, India. It was built by the Pallavas in the early8th century CE. It is famous for its splendid *vimana*. This temple was built by Pallava King Narasimhavarman II (Rajasimhan). it is in circular shape the Architecture .

The name Iravasthalam means Irava - Immortal, Sthalam - place, a placewhich gives immortality.

The temple is classified as one of the minor shrines of Kanchipuram. The temple has sculptural representation indicating the various legends from Hindu scriptures.



FIG 20 CIRCULAR GARBHA GRIHA AT IRAVATANESHWARA TEMPLE

2.1.3. Sri Sundararaja Perumal Kovil

The temple is located about 35kms East of Madurai AND 4kms North of Tirupachethi.the temple in its current form is said to date back to 13th centuryAD and to rule of kulasekara pandya.





FIG 21 CIRCULAR GARBHAGRIHA AT SIVAGANGAI TEMPLE

2.1.4. AUROVILLE - MATIR MANDIR



FIG 22 MATIR MANDIR @ PONDICHERRY

The four pillars support the structure of Matrimandir, these four pillars solely symbolizes the four aspects of mother.

South Pole - Maheshwari, North Pole – Mahakali, West Pole – Mahasarasvati, East Pole – Mahalakshm

The temple consists of a meditation chamber which is enveloped by a flattened sphere with conical roof, white marble wall, floor covered with whitecarpet.

The chamber is located in the upper hemisphere with its floor positioned at the widest point of the shell.

Sunshine entering from the roof is directed to a huge crystal globe whichhelps mysteriously to focus for meditation.

The four key pillars that support the structure of Matrimandir and the Inner Chamber, have been set at the four directions.

The Amphitheater fully covered with red Agra stone which is used for lateafternoon gatherings of a meditative nature.



FIG 23 MATIR MANDIR MEDITATION HALL AND TOP VIEW OF MATIRMANDIR

2.2. TRADITIONAL CIRCULAR TEMPLES IN KERALA

SRI KOVIL

The inner sanctum sanctorum where the idol of the presiding deity is installed and worshiped. It shall be an independent structure, detached from other buildings with no connections, and having its own roof shared with none.



FIG 24 SRI KOVIL AT KODUVILLA , KERALA

The Sri-kovil does not have any windows and has only one large door opening mostly towards the east (sometimes it happens towards the west, whereas a few temples have a north-facing door as its specialty, while no temples will have a south-facing door).

The Srikovil may be built in different plan shapes – square, rectangular, circular, or apsidal. Of these, the square plan shows an even distribution throughout Kerala.

The circular plan and the apsidal plan are rare in other parts of India and unknown even in the civil architecture of Kerala, but they constitute an important group of temples.

The circular plan shows a greater preponderance in the southern part of Kerala, in regions once under the influence of Buddhism. The apsidal plan is a combination of the semi-circle and the square and it is seen distributed sporadically all over the coastal region. The circular temples belong to the Vasara category.



FIG 25 TYPICAL SRIKOIL KOTTAYAM AT KERALA

A variation of circle-ellipse is also seen as an exception in the Siva shrine at Vaikkom. Polygonal shapes belonging to the Dravida category are also adopted rarely in temple plans but they find use as a feature of shikhara.

For the unitary temples, the overall height is taken as 13/7/ to 2 1/8 of the width of the shrine, and categorized into 5 classes as i.e.; santhika, purshtika, yayada, achudha, and savakamika – with increasing height of the temple form.

The total height is basically divided into two halves. The lower half consists of the basement, the pillar or the wall (stambha or bhithi), and the entablature (prasthara) in the ratio 1:2:1, in height.

Similarly, the upper half is divided into the neck (griva), the roof tower (shikhara), and the fonial (Kalasham) in the same ratio. The adisthana or foundation is generally in granite but the superstructure is built in laterite. Theroofings will be of normally taller than other temple structures.

2.3. TRADITIONAL CIRCULAR TEMPLES MADHYA PRADESH

2.3.1 SANCHI STUPA @ Madhya Pradesh

The monuments at Sanchi today comprise a series of Buddhist monuments starting from the Mauryan Empire period (3rd century BCE), continuing with the Gupta Empire period (5th century CE), and ending around the 12th century CE.It is probably the best preserved group of Buddhist monuments inIndia.

The oldest, and also the largest monument, is the Great Stupa also called Stupa No. 1 initially built under the Mauryans, and adorned with one of the Pillars of Ashoka.

During the following centuries, especially under the Shungas and

the Satavahanas, the Great Stupa was enlarged and decorated with gates and railings, and smaller stupas were also built in the vicinity



FIG 26 VIEW OF SANCHI STUPA AT MADHYA PRADESH

Simultaneously, various temple structures were also built, down to the GuptaEmpire period and later.

Altogether, Sanchi encompasses most of the evolution of ancient Indian architecture and ancient Buddhist architecture in India, from the early stages of Buddhism and its first artistic expression, to the decline of the religion in the subcontinent.


FIG 27 PLAN OF MOUNUMENT ON THE HILL AT SAMCHI

2.3.2. Chausath Yogini Temple@ Madhya Pradesh

The **Chausath Yogini Temple, Mitaoli**, also known as **Ekattarso Mahadeva Temple**, is an 11thcentury temple in Morena district in the Indian

state of Madhya Pradesh. It is one of the few well-preserved Yogini temples in India. The temple is formed by a circular wall with 65 chambers,

apparently for 64 yoginis and the goddess Devi, and an open mandapa in the centre of a circular courtyard, sacred to Shiva.



FIG 28 CHAUSATH YOGINI TEMPLE @MADHYA PRADESH

The design of the Indian Parliament's Central Hall building is circular to represent the Ashoka Chakra, a Hindu symbol that literally translates to "wheel of the law," which is also on the country's flag.

Chausath Yogini templeARCHITECTURE

Date established

9th century CE

Dated to 1323 CE the temple was built by the Kachchhapaghata kingDevapala

The temple is on a hill about 100 feet (30 m) in height; there are 100 steps to climb up to the entrance. It is circular with a radius of 170 feet (52 m), while inside it has 65 small chambers, each with a mandapa which is open and a facia of pilasters and pillars.

The roof of the ring of shrines is flat, as is that of the central shrine to Shiva; the circular courtyard is hypaethral, open to the sky, with an open porch as itsentrance.

The exterior surface of the outer wall, unlike other Yogini temples which are quite plain outside, was decorated with statues of couples flanked by maidens, mostly now lost or badly damaged.

Each of the chambers around the inside of the perimeter wall now contains an image of Shiva. originally these contained 64 Yogini images and probablyone image of the great goddess Devi.

The temple is therefore known as Chausath Yogini Temple (*Chausath* being the Hindi for "Sixty four").

It is said that the roofs over the 64 chambers and the central shrine had towers or shikharas, as those at the Chausath Yogini Temple, Khajuraho still do, but that these were removed during later modifications.

The central shrine's roofing slabs are perforated to allow rainwater to drain through pipes to a large underground tank.



FIG 29 HILL TOP CHAUSATH YOGINI TEMPLE

The temple is in the Seismic Zone III region and has survived several earthquakes, seemingly without any serious damage.

This fact was cited when the issue of safety from earthquake effect of the circular Parliament House, its design supposedly based on the Mitaoli temple, was debated in the Indian Parliament.



FIG 30 CHAUSATH YOGINI TEMPLE @ HIRAPUR

The **Chausath Yogini Temple** (64-Yogini Temple) of Hirapur, also called Mahamaya Temple, is 20 km outside Bhubaneswar, the capital

of Odisha state of Eastern India. It is devoted to the worship of the yoginis, auspicious goddess-like figures.

Hirapur's yogini temple is a tantric shrine with hypaethral (roofless) architecture as tantric prayer rituals involve worshipping

the *bhumandala* (environment consisting all the 5 elements of nature - fire, water, earth, air and ether), and the yoginis believed to be capable of flight.

The yogini idols represent female figures standing on an animal, a demon or a human head depicting the victory of Shakti (Feminine power).

The idols express everything from rage, sadness, pleasure, joy, desire and happiness. The number 64 finds its reference in Hindu mythology in forms such as Kālá for time, Kalā for performing arts etc.

Such temples dedicated to yoginis, although rare, are also seen at Ranipur-Jharial site of the Balangir district in Odisha and seven other places in India.

The temple is believed to have been built by Queen Hiradevi of the Bramhadynasty during the 9th century.

The temple complex is now maintained by Archaeological Survey of India.

ARCHITECTURAL CHARACTERISTICS :

The temple is small and circular, only 25 feet in diameter. It is hypaethral, and built of blocks of sandstone. The inside of the circular wall has niches, each housing the statue of a Goddess. 56 of the 64 idols, made of black stone, survive.

They surround the main image at the centre of the temple, the Goddess Kali, who stands on a human head, representing the triumph of the heart over themind.

Some historians believe that an idol of Maha Bhairava was worshipped in theChandi Mandapa.

The temple seems to follow a mandala plan in a way that concentric circles are formed while a Shiva at the center inside the inner sanctum is roundly surrounded by four Yoginis and four Bhairavas.

The circle is reached via a protruding entrance passage, so that the plan of the temple has the form of a *yoni*-pedestal for a Shiva lingam.



FIG .31 PLAN OF CHAUSATH YOGINI TEMPLE

2.4. Traditional Circular adobe in Gujarat

BHUNGA HOUSES IN GUJARAT



FIG 32 MAP OF KUTCH, GUJARAT

Kutch district is divided in two major parts:

Rann of Kutch – It is a wet and dry region without any settlements. Salt flat lands are prevalent in summer and flooded in rainy season.

Kutch – The area is dry with settlement both traditional and modern. Topography -Whole Kutch region is flat with grasslands, not much vegetation.

Bhungas, circular mud huts, are both resilient in the face of quakes andcentral to the Kutch identity.

Bhungas – a unique type of circular mud hut – are closely linked to theidentity of Kutch desert areas of Gujarat.

After an 1819 earthquake that caused severe damage to the lives and properties, the people of Kutch came up with the circular design of bhungas, which has been in use for nearly 200 years now.



FIG 33 ELEVATION OF BHUNGA HOUSES

Bhungas are traditional houses unique to the Kutch region in Gujarat. The houses are circular walled with thatched roof. They are known for their structural stability in earthquakes and for being climate responsive. It also protects against sandstorms and cyclonic winds.

It is constructed using locally available materials like clay, bamboo, timber, etc. Structurally the roof is placed on two thick wooden posts placed across the circular walls. These two posts bear the weight of the roof. Wooden framed windows are set at a lower level for cross ventilation.

The low hanging roofs cover the walls against direct sunlight and add to the insulation from the environment. The thatched roof is built on top of the walls resting on a spiral frame forming a cone.

The traditional bhunga requires periodic maintenance, a regular application of lipai or lime plastering to the walls and floor, and the replacement of the dried grass on the roof. The exterior walls are adorned with colourful

paintings while the interiors are decorated with exquisite mud and mirror work.

The Earthquake- Proof Huts of Kutch

Even after the severe **earthquake of 2001**, it was seen that despite being very close to the epicenter of the earthquake, bhungas stood firm while manyother buildings were devastated.

The diameter of a bhunga is approximately 18 feet and has a depth offoundation up to 24 inches.

Lightweight thatched roofslow walls plastered with mud,

twigs, and dung and an independent circular structure without any cornershave made these bhungas disaster-resistant.



Fig. 1: Flow of air acc. to Bernoulli's principle of pressure differences (Plan)



FIG 34 WIND FLOW IN CIRCULAR HOUSE IN GUJARAT

Bhunga is circular in plan having an inner diameter typically between 3m to 6m, generally has only three openings one door and two small windows.

Bhungas are connected through plinths and circulation is also carried out in that way . A cluster of Bhunga is built on one plinth usually the cluster contains settlements of one whole family.

All these features are helpful against the lateral forces of both earthquakes and storms. Moreover, the mud walls of the bhungas are thick and thus the

surface is less susceptible to heat. The small openings keep the room cool in the searing Kutch summers and warm in harsh winters.



Typical cross sectional view FIG 35 CROSS SECTION OF BHUNGA HOUSE

The circular shape does not obstruct the wind and hence reduces pressure on the structure during cyclones, another frequent occurrence in the region.

Bhungas, with their elaborate design and artistic elegance, portray Kutch culture, tradition, and lifestyle, They demonstrate the ecological, social, and aesthetic aspects of the region.



Bhungas, with their elaborate design and artistic elegance, portray Kutch culture, tradition, and lifestyle, They demonstrate the ecological, social, and aesthetic aspects of the region.



FIG 36. PLAN ALONG WITH ELEVATION OF BUNGA HOUSE

The components required for roof's construction are:

One horizontal beam (diameter 15 to 18 cm). – A base for the verticalkingpost - patli - size 5x7x25.

A central kingpost (ranging from 180 to 270 cm, diameter 10 cm).



FIG 37 INTEROR VIEW OF BHNGA HOUSE

A cone - at the top of the kingpost (diameter 40 cm, 45 cm high). Baboo wood rafters forming the backbone of the roof – VALI(having adiameter between 6 365 cm long).



FIG 38. Step by step procedure of Roof construction of Bhuga House

Culms of split bamboo which constitute the secondary warping - KHAPATIS – (diameter 2 .5 cm, length 365 cm). – Rope - KATHI -, (1.25 cm thick. 30 kgof rope are required). – Straw - KHEEP – (for roofing)



FIG . 39 PLAN OF BHUNGA HOUSE

The conical roof of a Bhunga is supported at its crest by a vertical central wooden post, which rests on a wooden joist. The base of the roof and the wooden joist are generally directly supported on Bhunga walls.

Sometimes, the roof load on wooden joist is transferred to diametrically placed timber posts (vertical members) adjacent to the cylindrical wall.



FIG . 40 CEILING OF BUNGA HOUSE AND VIEW OF BUNGA HOUSE

This reduces the roof-load on the walls. In several Bhungas, the roof joist is not directly supported on the cylindrical walls,

but is supported by two wooden vertical posts outside the Bhunga, which further improves seismic resistance of the inertia force generated in the roof.

In some instances, reinforcing bands at lintel level and collar level have been used to provide additional strength.

These bands are constructed from bamboo or from RCC. These increase the lateral load-carrying strength greatly and increase the seismic resistance of the Bhungas.

2.5. Traditional Circular Temple in Rajasthan

Bairat Temple City Bairat, Rajasthan, India.

Ashoka also built the Mahabodhi Temple in Bodh Gaya circa 250 BCE, a circular structure, in order to protect the Bodhi tree under which the Buddha had found enlightenment. The Bairat Temple is also a round structure, which can be seen through archaeological remains





FIG 41. VIEW OF BAIRAT of temple



FIG 42 PLAN OF Bairat Temple

2.6. NEPAL DWELLING UNITS

Most of the houses in the hills of Nepal are rectangular as they are built parallel to the terraced slope. Are rectangular forms a good choice or should people rather build their houses in square shapes or even round?

The shape of the plan of a house has an important influence of its stability against earthquakes. The square shape is better than a rectangular shape. The best is a round shape and the worst a L-shape.



Fig.43 Nepal mud dwelling

A 150 years old rounded house in western Nepal survived during 1934, 1988 and 2015 earthquakes without any damage.



Fig.44 Double storey mud circular dwellings

Vernacular dwellings in hills: Earthquake Resilience

In the mid-hills of Nepal basically the Gurung and Magar settlements (indigenous groups in western mid-hills of Nepal) are dominant.

In this region people have developed a unique tradition of housing construction. These are called as **Ghumauro dhi** locally.

The rounded structures constructed from stone masonry with countable fraction of timber elements are excellent examples in earthquake resilientfeatures.

Ghumauro dhi is a symmetrical circular construction, usually one to two storied where timber elements are introduced in the form of openings, slabsand struts at various levels.

The housing technology also incorporates many aspects of earthquake resistant features like symmetrical construction, high ductility, proper binding of housing units, among others.

Such features were developed from continuous trial and error efforts after several past disaster events.

2.7. KAMBALATHU NAYAKAR COMMUNITY HOUSES@THENI,DINDIGUL

Kambalattans are also called as Tottiyans.Tolli)ans are "Telugu cultivators" .

A kambli (blanket) is spread on which is placed a kalasam filled with water, and containing margosa leaves, and decorated with flowers. Its mouth is closed by mango leaves and a coconut.

The patron deities of the caste are Jakkamma and Bommakka, two women "who committed sati. The majority speak Telugu in their houses.

Both men and women arc supposed to practice magic. and arc on that account much dreaded by the people generally. They are especially noted for their power of curing snakebites by means f mystical incantations, and the original inventor of this mode of treatment has been deified under the name Pambalamman.

Nine kambalams : Kappiliyan, Anappan, Tottiyan. Kolin Tottiyan. Kuruba. Kummara. Medara. Odde, and Chakkiliyan.

Most of them are Vaishnavites, some of whom employ Brahman priests. but the majority of them are guided by gurus of their own, called Kodangi Nayakkan.

2.7.1 CASE STUDY - CIRCULAR DWELLING SETTLEMENT @DINDIGUL

APPINAYAKANPATTI-AYYALUR, DINDIGUL



Fig 45 Map show the location of kambalathu nayakars houses @dindigul



Fig 46 Map show the location of kambalathu nayakars houses @Dindigul

2.7.2 CASE STUDY - CIRCULAR DWELLING SETTLEMENT @ SALEM

Ruppamp	-latta						
Jalakandapuram		Tharama	analam	Pagalpath	14 m	Kannankuric	DI.
vadathur	Doraman	galam Desayili	Boomina akku Maramangali	ickenpatti athupatti	Natasothicat	Penya Conna Pudur Alixutti	1 (a) av
	Poolarrato	- Stein Prant Road	Salem -	Kolapatty	Soramangalam	Salem	apet
		Pappampadi			Periya Puthur N	Erumaparay.	am
		Medu	Edaganasalai		Konzalar Datt	Seelanaickenpath	
3h	Kach	iupalli Reddi	yur Etampillai	Chine a	Paris Paris	Nalikalpatti apatti	500
Ко	nganapuran	1	Vembadithate		Vaniyambadi	Panamarathupatti 1	Thippe
Vel	taiyampatay.	m Ma	ukapa orit chavadi A	layam Va Nayampatti	zhakuttapatti	Mallur Keeranur	
		- and the	Kal	ipatti	Vennandur	HIN 7	
1.00					Alamanatt	thanur	1.00
inkadu			Mailasam	usdram .		Karadiyanoor	
Sankasin		Athappampatty			Ras Nagar v Nagar	am .	
San	KQC .	State Land State	Karumanoor	and the second second	@2011 Good	e - Man data Reptinu sha	-Sec.

Fig 47 Map show the location of kambalathu nayakars houses @ Salem

The city is surrounded by hills nagaramalai in the north side, jeragamalai south side, kanjanamalai west side, godumalai in the east side.

This community (kambalathu nayakar community)people usually settle in the mountain region where they like to live in peaceful surroundings.natural material will be easily available in those regions.



FIG 48 Temple Circular Temple @salem

No windows has been provided in the houses .lighting and ventilation from 3feet wide doorway and 1 feet opening between the wall and the roof.

The one feet gap is provided to protect the wood used for construction fromtermites.

2.7.3 Materials used in the circular dwelling units are

Wall - stone is used as material no plastering has been done.stone material for wall which penetrates less amount of heat.

Roof height is about 8 feet from the wall so air circulation is more.

Flooring - Muram flooring has been done. Cow dung has been used in the flooring which gives cool effect to the interiors.

HOMBARAI

- Thombarai is a circular mud wall structure which is used to preserve the grains for more than one generation .
- D Poolankodi,alanjikodi,oonankodi,thuthimaar,nochi maar, viralikodi these are available near the villages (forest) which is used for construction. Dry it for 3 to 4days then these are tied together in circular form then it is plastered with mud on both the sides which is locally available. Then it is finished with cow dung weekly once.
- □ The size is about 10' x 10'. The height is 10'.
- Roof kpathattai which drain the rain water out , it FIGURE14.0 23 : THOMBARAI protects the wall and the grain from rain.





Fig. 49 Thombarai - to store grains ,ceilling plan of circular structures

2.7.4. CASE STUDY - CIRCULAR DWELLING SETTLEMENT @ THENI



Fig. 50 Map showing the location of kambalathu nayakars houses @ Theni



Fig 51. view of kambalathu nayakars houses @ Theni

In a single compound there are 3 to 4 dwelling units are present.centre part is open space where various activity is happening like they used to dry things sit or relax during evening and night time.



Fig 52 Left picture :Circular mud house

Right picture:Concrete Structure

Mud block structure

Mud is the oldest and widely used construction material.

According to the 2011 census of India, the walls of 23.7% households in India are constructed with mud.

Mud structures are eco-friendly with a very low embodied energy, and use a low quantity of nonrenewable materials, thus leading to sustainability.

The thick mud walls have high thermal mass and reduce indoor temperaturefluctuation.

Hence, they are preferred in arid regions where the diurnal fluctuation of ambient temperature is high.

In the investigated building, sun-dried mud blocks have been used to construct the walls.

Mud blocks with one side terracotta tiles are used in the external walls to prevent water penetration and erosion from the rain water.

CHAPTER 3

BENEFTIS OF CIRCULAR STRUCURES

- 1. Less embodied energy
- 2. More Energy Efficient
- 3. Earthquake and Wind Resistant
- 4. Cheaper to Build
- 5. Better Acoustics
- 6. Natural Climate Control
- 7. Maximum Day Lighting and Solar Energy
- 8. Round Houses are incredibly flexible.

Less embodied energy

WIND MOVEMENT FOR CIRCULAR ,SQUARE,IRREGULAR SHAPE



A round home is m

ventional rectangular homebecause there is less

dead space (i.e. corners) for cold air to collect and there is less drafting because the wind diffuses around the building rather than catch a large solid wall.

A round house with a curved roof has a lower floor surface area and is less exposed to the elements. This makes the house more energy efficient than arectangular building.

EARTHQUAKE AND WIND

Withstand extreme weather conditions: Multiple interconnected points, they are stronger and more flexible. Not only are they resistant against earthquakes, but their curved roofs are also less susceptible to getting lifted during hurricanes. This is because the strong wind flows around the dome-like structure rather than around it.

A Round House has dozens of interconnected points which give it a unique combination of flexibility and strength — qualities that make them significantly stronger than rectangular buildings during earthquakes.

Winds and Tsunami waves move naturally around a round building rather than getting caught on corners. A rounded roof also avoids 'air-planing' where strong winds can lift the roof structure off the building.

A Round House has dozens of interconnected points which give it a unique combination of flexibility and strength — qualities that make them significantly stronger than rectangular buildings during earthquakes.

Winds and Tsunami waves move naturally around a round building rather than getting caught on corners. A rounded roof also avoids 'air-planing' where strong winds can lift the roof structure off the building.



AIR FLOW

FIG.53 Air flow in circular buildings

<u>Cheaper to build:</u> these house styles don't require as many materials as other types of homes. They are simple to design, and take less time to build.

<u>Better insulated:</u> the round shape of the house means less noise penetrates from the outside and less noise comes out from the inside.

Celtic tribes lived in Ireland and typically lived in round style houses.

Extremely flexible:

Not all round houses have round rooms. But their bay windows allow you to enjoy the panoramic views. The interiors of typical round houses are usually open layouts that can be customized to suit your needs. This makes such houses incredibly flexible when planning your indoor living spaces.

Efficiency.

The natural thermal dynamics of a round space uses no external energy to circulate air.Warm air naturally rises until it reaches the insulated ceiling.

It then moves up the domed surface until it reaches the center skylight, which is cooler, and the air reacts by descending to the floor where it moves across to the walls and rises again until it meets the skylight and drops again.

This action constantly circulates the air and temperatures in the home, draftfree.

Sound:

The acoustics of a circular space are extraordinary.

The curved ceiling both softens and brightens the sound inside the building. The shape also prevents noise from penetrating in from the outside.

Sound waves dissipate as they wrap around the building, shielding the interior from loud outside noise.



Fig 54 roof- Construction ELEMENTS

<u>Strength.</u>

The roof structure of a round home incorporates a unique architectural design that has its origins in the mountain steppes of Central Asia.

Roof trusses meet in a center ring, producing inward and outward pressure which holds the roof in a state of compression.

In modern round buildings using the ancient yurt design, one to three airplane-grade steel cables circle the outer perimeter where the trusses meetthe wall and hold the natural outward thrust.

Because of this combination of a central compression ring at the top of the roof and the encircling cables, where the roof meets the walls, long roof spans are possible without any internal support system like beams or posts.

The interconnected tension in the building goes all the way to the ground and uses gravity and compression to hold it together with incredible strength.

Positive energy.

Our ancestors also understood another, less measurable, aspect of circular living. Living in a round home provides a balance of looking inward and outward, looking out at the natural environment and surroundings but then coming in again to the self and the heart.

A 21st-century round home built with modern materials can be a safe, efficient and healthy home of the future with roots in the past.

Space efficiency in circular adobe houses

A circular plan is seen to be less space efficient than a rectangular plan due to the fact that it is difficult to fit with commercially built furniture. However, this is not an argument when talking about general buildings.

While most of the areas using adobe construction for residential buildings arein developing countries their adobe houses are small due to their limitation of construction technologies. They may have only one or two separate living areas in one building space. The furniture is simple and maybe built from natural material matching with their earthen walls.

Most of the furniture in adobe house are built-in and connected to the wall panels to leave the centre area open to be used as the hall way (Maneewong2009).

Beds, tables and chairs can be made by earth material. Shelves can be easily carved into the adobe walls.

Roy (2006) claimed that circular is a simple shape to build in term of enclosing the maximum amount of space with the least amount of perimeterwall material.



Fig. 55 shows the space efficiency of circular adobe houses.

cylindrical walls (Vanggaard 2003). Therefore, a circular shape is easier to construct when compared to other shapes.

CHAPTER 4

CIRCULAR STRUCTURES IN OTHER AREAS



Fig . 56 Apple Park @ California

Apple Park is the corporate headquarters of Apple Inc., located in Cupertino, California. It was opened to employees in April 2017



Fig: 57 Camden Roundhouse

Railway Roundhouses

Interior view of the Camden Roundhouse, built as a locomotive shed and now an entertainment venue.

The Narrenturm, Vienna 1784, a hospital for the confinement of the mentallyill, from Dieter Jetter



Fig :58 Beijing, the Temple of Heaven

In Beijing, the Temple of Heaven is a conical structure that sits adjacent to a three-tiered circular marble altar used for imperial sacrifices during the Ming and Qing Dynasties. The circle represented the heavens, while a neighboringsquare depicted the Earth.

Roman amphitheaters, including the Colosseum, for example, were designed as circles or ellipses to place the focus on one main event, such as gladiatorial battles.



Fig.58 Roman amphitheaters and St. Peter's Piazza

St. Peter's Piazza, the square leading up to the main Vatican building, features two semicircles that enclose the space, meant to personify "the motherly arms of the church" welcoming people into the area.

Egyptians first approximated the value of **pi**, the **intrigue of circles** lives on.

Rondavels

Rondavels form the core of the investigation and merely highlights the occurrence of the circle as a spatial solution – one aspect of the investigation into the origins and history of the rondavel. For this reason, rondavels will not be analysed in detail in this article. Some general observations need to be highlighted though.

Rondavels remain significant vernacular building types in the entire classification and variety of form types of vernacular farm architecture. Interms of farmyard layout and spatial arrangement, rondavels can be clustered into two broad categories:

(a) as separate buildings to the main residence and

(b) as form type defining or included into the floor plan and spatial solutionscheme of the main residence.

Where rondavels occur as annexes to the main farm residence they were used as a detached kitchen, a milk room (where milk is separated), a meat room (where meat is prepared after slaughtering of an animal), additional accommodation (sleeping facilities for visiting guests or as detached rooms for the teenage boys) or as additional work space (either for the farmer – as an offifice or for the housewife).

Currently, rondavels are often used as space where farm workers are trained or where housewives assist in the administration of the farming activities.



Fig: 59 Rondavels Farm Residence

Small rondavel constructed with blocks of dolerite and sandstone quoining around the window and as window sill

The occurrence of rondavel houses or rectangular dwellings with a single or more than one rondavel (or circular room) attached to it is not the rule of thumb for early European vernacular architecture but many examples exist – to the point that it can be considered as a signifificant form type in the vernacular architecture of several regions.



Fig .60 Rondavel dwelling with small gable building at the back, on theseasonal winter farm of the Bosman family

CHAPTER 5

EARTHQUAKE RESISTANCE OF CIRCULAR ADOBE BUILDINGS

Seismic Capacity Comparison between Square and Circular Plan AdobeConstruction

5.1 Effect of shape on earthquake resistance

The behaviour of a building during an earthquake depends critically on its overall shape, as well as on how the earthquake forces are transmitted from the ground.

Ambrose and Vergun (1985) cited that the building configuration was an important factor in determining the fundamental period of the building which also affected the amount of seismic forces.

Arbabian (2000) states that overall layout of the building is one of the most important elements in building design. Earthquake damage in buildings with significant irregularity are found to be five to ten times worse than buildings with essentially regular layout (Booth, Arup & Partners 1994).

The shape determines the magnitude of the seismic forces which act on the building and their distribution:

1. distribution is important in the vertical direction in section as well as the horizontal direction in plan. Therefore in the planning stage it is very important that architects.and

2. engineers work together to ensure that a good building configuration hasbeen designed and unsuitable features are avoided.

Although traditional rectangular adobe buildings are often damaged in even moderate earthquakes, some shapes of buildings show superior performance even when located in regions of high seismic risk such as India, etc.

Their improved performance is due to the local people having learned the principles of seismic resistant construction by a " trial and error" process which has led to suitable construction methods for seismic areas.

"... The behaviour of a building during earthquakes depends critically on its overall shape, size and geometry, in addition to how the earthquake forces are carried to the ground.... The shape of the building has significant bearing on the performance of the building during strong earthquakes..."(NICEE 2002b)

Mauro Sassu (n.d.) states that the **circular floor plan of vernacular building**s offers the **best resistance to seismic forces,** however, a box shaped building creates troubles with out-of-plane forces and separation at the wall corners.

Circular earthen houses had been built in many regions of high seismic risk such as India, Malawi and China.

These houses have all shown good seismic performance. Sufficient seismic behaviour of these existing houses confirmed that it is possible to improve the seismic resistance by considering simple factors such as the architectural configuration.



Fig .61 Kutch Mud Houses EARTHQUAKE SAFE CIRCULAR ADOBE HOUSES

if we constructing the circular building in the small area then it is so difficult to construct because we cannot provide the circular beam(curved beam) but if the area is large where we are constructing the spherical building then we can easily construct the curved beam.

If the width increases the deflection values goes on increasing simultaneously for rectangular cross section in the curved beam.if the width is constant and the breadth increases the deflection value is identical varyingin decimal units.

The value of deflection in the circular cross section in the rounded beam is less than the deflection in the rectangular cross section in the curved beam if the considered the dead load of the beam.

Due to using the circular building the cost of the building decreases the 15% to 18% as compared to the rectangular or normal shape building.



Fig : 62 circular building in the small area and interconnected points in a round home

There are dozens of **interconnected points** in a round home. These are sites where engineered components- like a center radial steel ring, engineered steel brackets, Seismic and hurricane ties, bolts and steel cables-connect the structural pieces and give the building a unique combination of flexibility and strength- qualities which causes them to be significantly safer in

severe weather conditions like earthquakes, extreme winds and heavy snow-fall where builders can connect parts of the building together.

Safety. Wind and tsunami waves move naturally around a round buildingrather than getting caught at and potentially ripping off corners.

And a rounded roof avoids "**Air-planing**" — a situation where a strong windlifts the roof structure up and off the building.

Seismic analysis of circular shape RC building

The main concept of using the circular shape building is that -the aerodynamic effect on the circular shape of the building is less as compared to the other shape of the building.

When we construct the highrise building then the effect of the wind is high attop of the building, so we provide the circular shape at the top of the building to reduce the effect of the wind.

There are soo many advantages of the circular such as less embodied energy, energy efficiency, and earthquake and wind resistance and less expensive.

There are two type of the circular shape buildings which is given below.

Circular buildings with courtyards

In this type of the building, there are open space inside the cicular building, which may be used for parking and other purposes.



Fig. 63 circular building with courtyads

Circular buildings without courtyards

There is no courtyard. The main disadvantage of this type of the circular building is that no open space inside the building which can be used asparking.



Fig.64 Circular building without courtyads



Fig.65 Circular building - Indian parliment and chausath yogini temple

As is evident from the examples of the discussed urban complexes and multifunctional structures, the ring and circle were and are a form present inurban planning and architecture.

5.2 Existing circular shaped adobe houses located in seismic areas to understand their seismic resistance.

5.2.1 Hakka earth buildings in China

These types of buildings are located in earthquake active zones, zone VI-VII



Fig .66 Tulou earthen building - Hakka house in china

Tulou Earth Building – Hakka Houses. The traditional residential buildings in the western part of Fujian Province in southeast China, Hakka earth buildings, were added to the UNESCO World Heritage

Fujian province has had a total of 52 earthquakes over time, with the mostsevere one measuring 4.9 on the Richter scale. In 1918 it withstood an earthquake measuring 6.2 on the Richter scale.

Recently, on 13th March 2007, 2 earthquakes measuring 4.9 and 4.7 on the Richter scale struck northern Fujian province. These earthquakes had affected 457,000 people and 5,969 houses in Fujian (FMG 2007)

Ole Vanggaard (2003) noted that a circular building, *Tulou*, has greater staticstability due to the shell action of cylindrical walls.

The cylindrical shell is further strengthened considerably by the rigid, horizontal and circular decks of each floor (membrane forces).

The outer wall construction using rammed earth has excellent static stability for the compression force and for transferring the lateral force.

The inner wall construction of timber-frame adds further rigidity and strength and being fixed in four directions the timber-frame creates an integrated matrix which restrains movement and enhances the overall strength of the structure.

5.2.2 Bhunga houses in India

About 50,000 people were killed and one million people were left homeless. Most of the brick masonry and concrete buildings in the district were destroyed. While the circular adobe-huts were still intact (Amir, January 2005).

The main peculiarity of the Bhunga house is its design. Generally ordinary houses are of square or rectangular shape whereas the Bhunga houses are of round shape. Bhungas are very popular due to their unique design feature.

The diameter of a Bhunga house is approximately **18-24 feet with afoundation depth of 24 inches.**

In the **2001 Kachchh (Gujarat) earthquake with 7.6 intensity on richterscale**, very few Bhungas experienced significant damage in the epicentre region.

The damage that did occur can mainly be attributed to the poor quality of construction materials used or improper maintenance of the structures.

Due to its robustness against natural hazards as well as its pleasant aesthetics, this type of housing construction is also known as **"Architecturewithout Architects"**.

During earthquakes, due to the circular shape of the walls of the Bhunga houses, inertia forces developed in the walls are resisted through shell action providing excellent resistance to lateral forces. In addition, the thick walls required for thermal insulation have high in-plane stiffness which provides excellent performance under lateral loads.

The roofing materials are generally very light weight. Since the roof is constructed from extremely ductile materials such as bamboo and straw, theperformance of these roofs is usually very robust.

Even in situations where the roof collapses, its low weight ensures that the extent of injuries to occupants is very low. In several Bhungas, the roof joist is not directly supported on the cylindrical walls, but is supported by two wooden vertical posts outside the Bhunga, which further improves seismic resistance of the inertia forces generated in the roof.

In some cases, reinforcing bands at lintel level and collar level have been used to provide additional strength. These bands are constructed from bamboo or from RCC.



Fig.67 Circular building During construction

These increase the lateral load-carrying strength greatly and increase the seismic resistance of the Bhungas.

Catastrophic earthquakes often leave un-imaginable destruction to property and claim thousands of lives. Building materials and structural design play avital role in the stability of the structures during earthquakes.



Fig .68 The circular form, monolithic construction, small openings, lightweight conical roof and low slenderness ratio of the walls makesthe Bhunga houses earthquake resistant.

5.2.3. Yomata houses in Malawi

A typical Yomata house is constructed generally in a circular shape plan, and it is for single family use. There is no window in this type of circular housing. The space between each house is approximately 3 meters.

It has only one door with the size ranging from 1.50 to 1.70 metres in height, and 0.60 to 0.80 metres in width.

The diameter of the circular plan is about 3 to 4 meters.

The height-to-thickness ratio of wall is about 10/1. The height is generally about 2 metres. These types of buildings have a shallow foundation.


Fig.69 TYPICAL HOUSE OF YOMATA HOUSE IN MALAWI

The wall structure is made of mud bricks. However, some houses are constructed with wooden poles reinforcement inside the earthen wall.

A thatched roof, a central pole of 0.2 - 0.3 m in diameter is placed in the centre to receive sloping members (60 - 70 mm diameter) acting as raftersspanning to circular walls. The angle of the pitched roof is typically not less than 20 degrees. The grass depth is about 25mm forming a thatched roof.

5.2.4. Building Performances in earthquakes

Mauro s states that typical yomata houses performed well during the earthquake and he pointed out the main reason as follows.

The Circular Floor plan achieves more desirable seismic performance whencompared to rectangular building plan. The latter creates problems with wall separation at the corners and out of plane collapse.

Use of timber to reinforce earthen walls can increase ductility and secure the connections, and this ensures a good seismic response.

Lightweight roof structures result in much superior seismic performance when compared to the heavy roofs such as traditional adobe construction inBam, Iran.

Their traditional thatched roof reduces the mass on the top of wall which attracts lower seismic force due to inertia and also makes it safer againstfalling roof tiles.

Shows the comparison of their configurations which are related to theirearthquake resistance effects.

Building proportions	Hakka house (China)	Bhunga house (India)	Yomata house (Malawi)
Wall height-to-thickness ratio	13/1	13/1	13/1
Height-to-width ratio	3/10	8/10	6/10
Door opening in earthen wall	2.50 x 1.80	2.00 x 0.75	1.70 x 0.80
Window opening in earthen wall	1.00 x 0.60	0.60 x 0.40	-1
Total area of openings	Less than 0.3 x area of wall	Less than 0.3 x area of wall	Less than 0.3 x area of wall
Roof structure	Heavy-weight roof	Light-weight roof	Light-weight roof

Table 4.2: Comparison of the existing adobe houses' configuration

This table shows the important features of these buildings for seismic resistance such as their wall opening and slenderness ratios. All these buildings had small wall openings which contribute to their good seismicperformance.

These data show a better performance of circular shapes than square ones

In addition, it can be noticed that Yomata houses have shown good seismic performances, even when the total width of opening is more than 1/3 the distance between adjacent cross walls.



Fig.70 Square and circular specimens configuration and dimensions for stilt test -for seismic resistance



Figure 7.6: Tilting the square specimen and first crack appearing at 20 degrees.



Figure 7.7: The failure modes of the square specimen when tilted further.

Fig.71 Circular and square block first crack appearing and square block when tilted further

The failure mechanism of the square block is the static test was vertical corner was induced by shear or tearing trusses and followed by the overturning of wall panel.

A Lack of mechanism fixing at the corners allows greater out of plane displacement out of the wall panel. The top of the wall had larger response which caused a greater pounding impact thus inducing greater stresses that lead to the complete wall failure.



Figure 7.9: The failure modes of the circular specimens when tilted further.

Fig.72 Tilting the circular block and first crack appearing and when tilted further

For circular building , it was clear from the observation that the first crackingappeared on the side of the walls, starting from the top edge fig 7.8.

The other crack occured when the table was tilted further.

The model rapidly approached failure when the front part of the wall tented to rotate and eventually seperated from the rest of the model. **Source** :

The comparison of the results from the square and circular specimens were carried out.

The first cracking and the complete failure angles were used to calculate the maximum lateral force for both models at each stage. Table 7.2 and Table

7.3 give the comparative results of these static tilt-table tests.

	First shear crack	Complete failure
Angle (degrees)	20	25
Horizontal force (HF)	1.45 kN	1.78 kN
Percentage of the max. horizontal force compared to model own weight	34.3%	42.3%

Table 7.2: Results of the square specimen subjected to static tilt testing

Table 7.3: Results of the circular specimen subjected to static tilt testing

	First shear crack	Complete failure
Angle (degrees)	29	32
Horizontal force (HF)	1.73 kN	2.02 kN
Percentage of the max. horizontal force compare to model own weight	45.4%	53.0%

The results show that the circular adobe structure performed better than thesquare one with a higher percentage of horizontal force resistance.

Mauro Sassu (n.d.) also stated that a circular floor plan of vernacularbuildings offers the best resistance to seismic forces, and a box- shaped building performs poorly with out-of-plane forces and separation at the wall corners.

Ole Vanggaard (2003) noted that a circular building has greater staticstability due to the shell action of cylindrical wall which has excellent static stability to resist compression force and transfer lateral force.

1.Functional, such as defence, communication, hygiene, insolation 2.Structural: ease of marking out a circle and providing even layout of

structure and distribution of loads

- 3. Social
- 4. Aesthetic and prestige5.Emotional

Comprehensive earthquake damage statistics from around the world serve as clear reminders that research to improve the earthquake performance of adobe buildings is urgently needed. On the other hand, there are some historical earthen buildings which had withstood several seismic forces in recent centuries such as the

Hakka houses in China, the Bhunga houses in India, the Yomata houses in Malawi, and rammed earth buildings in Argentina. These existing earthen houses used different construction techniques and they were all of circular shape.

Norton (1986) states that, the proportion of a building is one of the factors likely to lead to building damage during an earthquake. A building of wrong size or shape can easily damaged by lateral motions.

Tomazevic (1999) also states that a regular layout in plan is preferred whenbuilding adobe buildings in seismic areas. Sufficient seismic behaviour of these existing houses confirmed that it is possible to improve the seismic resistance by considering simple factors such as the architectural configuration.

Minke (2001) noted that the shape of the plan might have influence on its stability in seismic areas and the more compact is a plan, the better is the stability.

CHAPTER 6

- 1. Temperature analysis
- 2. Roof surface temperature depend on (Material+depth)
- 3. Wall surface temperature analysis
- 4. Humidity level Analysis

6.1 TEMPERATURE ANALYSIS

Readings taken by using the dry bulb and wet bulb temperature tools from 6.A.M to 6.P.M AT KAMBALATHU NAYAKARS HOUSE AT DINDIGUL



DRY BULB TEMPERATURE READINGS

Fig. 73 Chart shows the temperature(dry bulb) reading on y axis and hours on x axis, the orange colour code indicates the outside temperature and theblue line indicate the indoor temperature.

Max.Out door air temperature - 40 deg.Max. Indoor air temperature - 30 deg.

S.NO.	TIME /HOURS	INDOOR DRY	OUTDOOR DRY
1.	6.00 A.M.	25	25
2.	8.00 A.M	26	26
3.	10.00 A.M	26	30
4.	12.00 P.M	30	40
5.	2.00 P.M	28	37
6.	4.00 P.M	26	35
7.	6.00 P.M	25	30

Table no . 01 Table shows the temperature(dry bulb) indoor andoutdoor temperature reading @dindigul

6.1. Wet bulb Temperature Reading



Fig. 74 Chart shows the temperature(wet bulb)

Chart shows the temperature on y axis and hours on x axis, the orange colour code indicates the outside temperature and the blue line indicate the indoor temperature.

Max.Out door air temperature - 35 deg.Max. Indoor air temperature - 26 deg.

S.NO.	TIME /HOURS	INDOOR WET	OUTDOOR WET
1.	6.00 A.M.	24	25
2.	8.00 A.M	25	25
3.	10.00 A.M	25	28
4.	12.00 P.M	21	30
5.	2.00 P.M	26	35
6.	4.00 P.M	26	29
7.	6.00 P.M	25	25

Table no . 02 Table shows the temperature(wet bulb) indoor andoutdoor temperature reading @dindigul

6.2 <u>ROOF SURFACE TEMPERATURE</u>



Fig. 75 Chart shows the Roof surface Reading

Above the roof - Blue colour indicates that the Max.Temp.45 deg. Below the Roof - orange colour indicates that the Max.Temp.30deg.

Since the roofing material (locally available material) and the construction technique they have gone is very old method .the height of the roof for circular building is 9feet (6 feet internal height).

S.NO.	TIME /HOURS	ABOVE ROOF	BELOW ROOF
1.	6.00 A.M.	15	30
2.	8.00 A.M	23	25
3.	10.00 A.M	40	30
4.	12.00 P.M	45	29
5.	2.00 P.M	44	28
6.	4.00 P.M	42	29
7.	6.00 P.M	35	30

Table no . 03 Table shows the Roof surtace above and belowtemperature reading @dindigul



Fig. 76 Cross section of circular Roof Structure temple @salem

MATERIAL USED FOR ROOF : Karumanj chohai, Kammanth thattai , cholathatai ,thatch roof.Bothai pullu- which is one type of leaf which is used for cooling purpose.

6.3 <u>Wall surface temperature</u>



Fig. 77 Chart shows the Wall surface Temperature Reading

Wall surface-the graph shows that the temperature inside the house remained lower during the day and higher at night than the out side

temperature.the internal temperature did not follow the external temperaturecurve.

Mud wall thickness is about 0.6m with cowdung as plastering.Maintenance plastering.Maintenance plastering with cowdung is done once in a week.

S.NO.	TIME /HOURS	OUTDOOOR	INDOOR
		TEMPERATURE	TEMPERATURE
1.	6.00 A.M.	24 DEG C	30 DEG C
2.	8.00 A.M	26 DEG C	28 DEG C
3.	10.00 A.M	30 DEG	30 DEG C
4.	12.00 P.M	35 DEG C	26 DEG C
5.	2.00 P.M	39 DEG C	25 DEG C
6.	4.00 P.M	34 DEG C	26 DEG C
7.	6.00 P.M	32 DEG C	32 DEG C

Table no . 04 Table shows the wall surtace indoor and outdoortemperature reading @dindigul



Fig. 78 Plan of the Kambalathu nayakars house with dimensions

6.4 Humidity Analysis

Circular houses at dindigul region - humidity level has been identified the indoor humidity level is by using **a hygrometer**. A hygrometer is a device that serves as an indoor thermometer and humidity monitor.



Fig. 79 Chart shows the Humidity Reading

Chart shows the humidity Reading blue line indicates the indoor reading and orange colour indicates outdoor humidity level of circular house at Dindigul

S.NO.	TIME /HOURS	OUTDOOOR HUMIDITY	INDOOR HUMIDITY
1.	6.00 A.M.	75	75
2.	8.00 A.M	70	72
3.	10.00 A.M	62	64
4.	12.00 P.M	55	55
5.	2.00 P.M	50	55
6.	4.00 P.M	50	50
7.	6.00 P.M	50	65

Table no . 05 Table shows the humidity indoor and outdoortemperature reading @dindigul Humidity level is high in indoor level is 75% at 6.00 A.m. in the morning and then it gradually slow down and reaches 65% at 2.00 P.m and further it slowdown by evening 8.00 p.m Out door humidity range varies from 75% and it slow down at 2.00 p.m and reaches 50% and then gradually increases to 70%.

6.5 Thermal comfort in vernacular architecture

Another important factor to consider during the construction of a building is the thermal comfort of the indoor space. However, in the past few decades, the thermal performance of the building is not considered during the designand construction phase.

This results in buildings with a poor thermal performance. After the building is constructured, the indoor thermal comfort is achieved using mechanical air- conditioning systems that are not only energy intensive but also eco- destructive.

This was not the case before the advent of the modern air-conditioning systems. Thermal comfort was achieved by designing the building to suit the local climatic conditions.

For example, **in hot regions**, buildings were constructed with low ventilation to prevent discomfort from the infifiltration of the hot outdoor air.

In dry regions, the temperature flfluctuation of the outdoor air is high. Hence, the buildings were constructed with a high thermal mass to reduce the temperature flfluctuation of the indoor space.

In **warm and humid tropical regions,** the ventilation in the indoor space was maintained high with wide building openings (windows and doors) facing the predominant wind direction, whereas the thermal mass of the building was low to avoid evening discomfort from the stored heat.

In solar-intensive regions, the dome structured roofs were used to reduce the solar heat gain, as they provide self-shading and reduce the surface areato volume ratio.



Fig. 80 Stablized mud block circular structure

CHAPTER 7 ENERGY SIMULATION



TOOLS USED : HONEYBEE AND LADYBUG, GRASSHOPPER



HONEY BEE WORK FLOW



Fig. 82 HONEY BEE - OUTPUT VISUALIZATION

DAYLIGHT SIMULATION

7.1 DAY LIGHT SIMULATION FOR SQUARE BUILDING



Fig. 83 GRID BASED VISUALIZING THE ANNUAL DAY LIGHT SIMULATION FORSQUARE STRUCTURE



GRASSHOPPER SCRIPT

To find the daylight analysis grasshopper - honeybee and ladybug plugin isused

Step 1 : Allocate the geometry and openings and shading surfaces in themass zone component.

7.3. Day light SIMULATION - Rectangular building



Grasshopper script -1



Fig. 84 Grasshopper script -2



Grasshopper script -3



Grasshopper script -4



Fig. 85 GRID BASED VISUALIZING THE ANNUAL DAY LIGHT SIMULATION FORRECTANGULAR STRUCTURE

7.4 Circular structure daylight factor analysis





Fig. 86 GRID BASED VISUALIZING THE ANNUAL DAY LIGHT SIMULATION FORCIRCULR STRUCTURE

7.5 BUILDING INFORMATION MODELLING

Building energy modelling software is used to find the energy cost,HVAC,lighting efficiency,pv panel efficiency ,plug load efficiency,roof construction,wall construction,window shades

7.5.1 Modelling FOR CIRCULAR SHAPE STRUCTURE IN DINDIGULREGION

LOCATION : DINDIGUL GEOMETRY : CIRCULAR SHAPESIZE : 36 SQ.M. MATERIAL USED : CONCRETE





Fig. 87 simulation Modelling Result FOR CIRCULAR SHAPE STRUCTUREIN DINDIGUL REGION









Fig. 87 simulation Modelling Result FOR CIRCULAR SHAPE STRUCTUREIN DINDIGUL REGION

7.5.2. <u>Modelling for Square Shape Structure in Dindigul District.</u> BIM SIMULATION :

LOCATION : **<u>DINDIGUL</u>** GEOMETRY : <u>SQUARE SHAPE</u>SIZE : <u>36 SQ.M.</u> MATERIAL USED : <u>CONCRETE</u>

MODEL : SQUARE





ENERGY COST AND BENCH MARK COMPARISION



DAYLIGHTING AND OCCUPANCY CONTROL AND LIGHTEFFICIENCY



INTERIOR VIEW OF THE SQUARE SHAPE STRUCTURE - DINDIGULREGION



ROOF CONSTRUCTION AND WALL CONSTRUCTION



WINDOW AND SOUTHERN WALL AND WESTERN WALL READINGS

Fig. 88 simulation Modelling Result Square Shape Structure in DindigulDistrict.

7.5.3. Modelling for Rectangular Shape Structure in Dindigul District.



7.5.4. Modelling for Circular Shape Structure in Chennai District.BIM SIMULATION :

LOCATION : CHENNAI GEOMETRY : CIRCULAR SHAPESIZE : 36 SQ.M. MATERIAL USED : CONCRETE











Fig. 89 Simulation Modelling Result Circular Shape Structure in ChennaiDistrict.

7.5.4. Modelling for Rectagular Shape Structure in Chennai District.

BIM SIMULATION:

LOCATION : CHENNAI GEOMETRY : RECTANGULAR/SQUARE SHAPESIZE : 36 SQ.M. MATERIAL USED : CONCRETE















Fig. 90 Simulation Modelling Result Rectagular Shape Structure in ChennaiDistrict

7.5.4. Modelling for Square Shape Structure in Chennai District.













Fig. 91 Simulation Modelling Result Square Shape Structure in ChennaiDistrict.

CONCLUSION :

SEISMIC RESISTANCE

The static tilt-table testing gives reasonable results when the seismic response of adobe structures is investigated. The result of these comparative experiments indicated a **better performance of the circular structures than the square ones.**

The outcome of this experiment provides simple and effective solutions for construction of new adobe buildings located in seismic areas, and it can helpto reduce building damage and death. The results were used to develop a methodology for designing circular adobe buildings to resist earthquakes in specific seismic zones and for specific site conditions.

This test outcome suggests that circular plans should be considered fordesign and construction of adobe houses located in seismic hazard areas. A comparison with window and door openings for these two shapes would be worthy of further investigation to confirm any advantages or disadvantages of circular buildings.

<u>The successful comparison tests between square and circular adobe walls revealed the following outcomes:</u>

Test results indicated that the static tilt-table testing gives reasonable results when the seismic response of adobe structures is investigated.

The result of these comparative experiments indicates that circular structures perform better than the square ones.

The outcome of these experiments gives simple and effective solutions forconstruction of new adobe buildings located in seismic areas.

Further comparative studies of square and circular adobe structures with openings in various configurations should be conducted to verify the advantages of circular structures and study the failure behaviour of the structures.

Test results challenge guidelines and manuals for adobe constructions as most of them recommend square layout for the most effective seismic resistant buildings.

Lack of experience and knowledge on circular adobe construction restricted its use for better seismic performance.

THERMAL PERFORMANCE

Thermal performance of Circular structures, in two regions the datas has been taken and by using simulation software like REVIT INSIGHT and RHINO GRASSHOPPER, HONEY BEE the final result has been identified.

In the same way for square and rectangular structure in two regions say chennai and dindigul region the datas has been collected by using simulation software like REVIT INSIGHT and RHINO GRASSHOPPER, HONEY BEE the final result has been identified.
All three geometrical shapes has same dimensions , wall thickness,Material,window allocation,location of the structure is same. that have merged traditional architecture with modern materials, was investigated during the transition period between summer 15th may month and winter 20 th month seasons

Table no. 06 Comparative analysis of the Energy cost for the Square, Circular, Rectagular structures



S.NO.	DESCRIPTION	CIRCULAR STRUCTURE	RECTANGULA F	RSQUARE STRUCTU RE
CHENNAI REGION - CONCRETE Material				
1.	ENERGY COST	28.1 USD/M²/yr	26.3 USD/M²/yr	26.3 USD/M²/yr
CHENNAI REGION - BRICK Material				
2.	ENERGY COST	28.1 USD/M²/yr	26.3 USD/M²/yr	26.3 USD/M²/yr
DINDIGUL REGION - BRICK Material				
3.	ENERGY COST	27.3 USD/M²/yr	25.7 USD/M²/yr	25.7 USD/M²/yr
4.	ENERGY COST	27.3 USD/M²/yr	25.7 USD/M²/yr	25.7 USD/M²/yr

Temperature Analysis of Circular Mud Structure - DINDIGUL Region

Considering 90% adaptive comfort limits, the indoor spaces of circular structures are comfortable all the time, and the remaining two structures are

comfortable most of the time and slightly cold during the late evening andearly morning hours.

The use of chola thattai,kambu thattai materials in roofs and the presence of Mud material in the walls are found to reduce the heat transfer through the structure significantly.

The increase in the thermal mass of the structure reduces the temperature flfluctuation and delays the time at which the temperature extreme are reached.

The maximum temperature of the roof interior surface is reached 30 deg c while the outdoor temperature is 40 deg temperature at 9.00 a.m.

Indoor air temperatures were lower than outdoor air temperatures in summer whereas indoor air temperatures were higher than outdoor in winter in these traditional buildings.

The maximum temperature of the mud wall @ 2.00 p.m the inside the building is 25 deg c and in outer mud wall temperature is 38 deg c.

Approximately 13 degC variation is there in the mud block structure (higherthermal mass)

Finally, it is clear from the investigation and discussion above that a circular layout for adobe construction is as space efficient and easier to construct than a square or a rectangular layout.

The hypothesis that people are unaware of the fact and lack information regarding circular-adobe building needs to be addressed.

Therefore, publication of this research and making the findings available to all areas using adobe construction methods may contribute to this area, and it can encourage future builders to use this type of construction. It will also challenge adobe researchers to further study circular adobe buildings.

REFERENCES

[1] E. Leroy Tolles, E.E.K., Frederick A. Webster, William S. Ginell. Seismic Stabilization of Historic Adobe Buildings : Final report of the Getty Seismic Adobe Project, The Getty Conservation Institute, Los Angeles, 2000.

[2] Norton, J. & Intermediate Technology Development Group. Building withearth : a handbook, IT Publications, Rugby, U.K, 1986.

[3] Minke, G. Earth Construction Handbook, Wit press, Bath, UK, 2000.

[4] Minke, G. Construction manual for earthquake-resistant houses built of earth, GATE - BASIN, ">http://www.gtz.de/basin>, 2001.

(5) Sassu,M. (n.d.). Vernacular Housing Construction, http://www.world-housing.net.

(6) Earthquake resistance of circular adobe buildings by Watcharin Jinwuth

(7) Walker, P. & Standards Australia. The Australian Earth Building Handbook, Standards Australia, Sydney, Australia, 2002.

(8) RPDåHYLþ, M. Earthquake-resistant design of masonry buildings, Imperial College Press, 1999.

(9) Uthai Phat Ra Kun, T. Build house from earth, Fueangfa printing Co.Ltd,2004.

(10) Vanggaard, O. Clan homes in Fujian, ChinaDwelling, 2003.

(11) http://www.basinsa.net/taranet/websitepages/basinsadefault.aspx&page =GenericLayoutBasinAlert.aspx?CatNavbarID=4492