Traditional Pol Houses of Ahmedabad: An Overview

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Received April 27, 2020; Revised June 11, 2020; Accepted June 26, 2020

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Abstract India has been rich in traditional and vernacular architecture throughout History. There were many traditional residential architecture typologies developed in the medieval period. The Pol houses of Gujarat are unique buildings that originated during this time and developed later on as per climate, using local building materials and the social needs of people. Due to globalization and the liberalization of the Indian economy in 1990, there has been a significant change in people's lifestyles and social systems. People feel that Pol houses are no longer able to fulfill the present need for residents. The importance of traditional Pol houses increased after the declaration of Ahmedabad's walled city as World Heritage City in 2017 by UNESCO. The method adopted for this study is a literature review. The analysis and discussions are divided into the following categories for understanding the urban context – a) origin and evolution of Pol houses, b) physical planning, and c) Pol houses' social system at the neighborhood level. The houses have been analyzed in various aspects, such as the spatial, environmental, behavioral aspects of design, and other aspects such as rainwater, harvesting, and earthquake resistance. The research concluded that the Pol houses have very functional design due to small neighborhood at the urban context to manage efficiently, climate responsiveness: streets, courtyards and use of sustainable building materials, use of rainwater harvesting to solve the scarcity of water in the present situation, use of construction and building materials to make it earthquake resistance structure. These houses also fulfill the aesthetic criteria because the ornamentation in homes is logically done, which is an integral part of the structure.

Keywords UNESCO, Traditional Indian Architecture, World Heritage City, Pol Houses, Ahmedabad

1. Introduction

India has a vibrant heritage and vernacular architecture

throughout History. Indians have developed this rich architecture in many centuries; the design of buildings has made up considering the climate, practical usage of space, and building materials for a particular place.

There are different residential typologies available in India, such as Haveli of Gujarat, Haveli of Rajasthan, Wada of Maharashtra, Nalukettu of Kerala, Chettinad of Tamil Nadu and Rajbari of Bengal. Pol Houses are also one of these categories available in Ahmedabad City of Gujarat. [1]

In 1990 the new economic policy of liberalization had led to globalization. Economic integration was the central phenomenon of globalization that is no longer just political or economic, but a cultural phenomenon as well. Increasing interaction and integration across borders due to globalization diminish differences between nations, causing global norms, ideas, and practices to dilute local cultures. Apartments or contemporary houses without a courtyard have replaced local traditional architecture as these can fit anywhere irrespective of climate, social, cultural background. [2]

Due to an increase in population and less land availability, it is collective thinking that high rise high-density apartments are required, which leads to no need for local traditional residential architecture. It is appropriate to mention housing in all ancient Indian cities like Jaipur, Ahmedabad was a low rise and high density. The primary purpose of high density can achieve by both the ways, either high rise or low rise. Many studies suggest that many Psychological issues arise due to living in high rise housing, so the other option of low-rise and high density should not be ignored. Most of the high rises built in India are not sustainable buildings, while the all traditional residential architecture of old cities of India is sustainable.

It is a very appropriate time for India to understand and recognize the importance of values associated with Heritage and vernacular residential buildings to balance both types of housing, i.e., high-rise high density and low-rise high density should achieve in the future.

There is a need to study Heritage and vernacular residential typologies to understand the principles of design applied in these residential buildings. This knowledge can be useful in designing new buildings in the future. Also, there is a need to conserve these heritage buildings for future generations.

Pol houses have been built around 300-400 years back and declared as a world heritage building by UNESCO in 2017 and situated in the old walled city of Ahmedabad. The walled city of Ahmedabad has its organic growth, and the walled city connects with the new city of Ahmedabad through four connecting bridges. There are 12 gates to enter into a city in ancient times. The area of the walled city is 5.78 sq. Km, and it has around 360 pols, and each Pol consists of 45-60 houses [3].

There are many issues persist living in Pol houses, and people have started migrating from the walled city to New Ahmedabad. The walled city's present population is around 3, 75, 000 as opposed to 5, 00,000 in 1991. People have also started demolishing the heritage buildings in the last two decades, and therefore, it is imperative to study Pol houses' present situation and propose interventions to conserve these Heritage buildings for future generations [3].

1.1. Aim

To analyze the urban design and design of houses of traditional Pol houses of Ahmedabad through literature review to understand the importance of these buildings to conserve for future generations.

1.2. Objectives

- a) To analyze the origin and historical evolution of Pol houses and to understand the present design context.
- b) To know the urban settlement pattern of Pol houses and to understand the context of Pol houses design.
- c) To understand the critical design aspects such as spatial, environmental, and behavioral to understand the unique features.
- d) To analyze the various other design aspects such as rainwater harvesting, earthquake resistance, and building materials and construction techniques to understand the unique features of the design.

1.3. Significance of the Study

- a) UNESCO declared the walled city of Ahmedabad as Heritage city in 2017, and the traditional Pol houses are one of the essential categories of buildings included in Dossier of Ahmedabad presented to UNESCO. This study involves the principles of design of Pol houses, which have not been covered in the Dossier of Ahmedabad. Hence, this study will provide a new dimension for heritage buildings.
- b) This study will bring awareness among the residents

of Pol houses and various other stakeholders such as the authorities of Ahmedabad Municipal Corporation, conservation architects to conserve the heritage buildings due to its unique design principles.

2. Methodology

The literature review is the primary method adopted for this study. This entire study has been done in four parts, as follows:

- a) The origin and historical evolution were studied as the origin of the city, the Pol neighborhood's growth, and Pol houses' historical evolution.
- b) The urban design settlement of Pol houses has studied as a neighborhood design concept, such as the size of plots, open spaces, streets, and gates.
- c) The spatial design has studied as disposition functions, space syntax, and other theories to understand Pol houses' spatial analysis. The environmental aspects of the design have been studied as thermal comfort, ventilation in the house of various seasons. The behavioral aspects have studied as a social system at the neighborhood level and social system at the house level. The aesthetic of the house has studied as the possible reasons for ornamental and types of ornamentation.
- d) The other aspect, such as earthquake resistance, has been studied as a construction system, building materials, and structural systems. Rainwater harvesting is considered as a system of collection, storage, and utilization of water. A study of the building materials took place under the following two categories- i) the use of local building materials and ii) their efficiency as sustainable building materials.

3. Analysis and Discussion

3.1. History of Pol Houses of Ahmedabad: Origin and Evolution

The Pol houses are situated in the walled city of Ahmedabad. The geographical location of Ahmedabad is 23.03°N 72.58°E and is the fifth most populated city of India. The city has a population of 5,633,927 as per 2011 population census. It is located on the banks of the Sabarmati River. [4]

Ahmed Shah founded the walled city of Ahmedabad in 1411 A.D. The city is almost semicircular and surrounded by a fortified wall. The fort wall was 8 miles in length, and there were 12 gates in the wall namely, Shahpur gate, Delhi gate and Dariapur gate in the North; Kalupur gate, Sarangpur gate and Raipur gate in the East; Astodia gate, Jamalpur gate and Dhediya gate in the South; Khanjahan gate, Raikhad gate and Khanpur gate in the west. Six more

gates were added to the city later. [5]

A royal palace built for Sultan Ahmed Shah is known as the citadel of Bhadra. Neighborhoods, residential areas, and localities, as shown in Fig 1, are known as "paras." Sultan Mehmed Begado's reign saw to the development of these architectural marvels. There were 360 -380 paras in that period. These paras areas were distributed among Sultan's commanders and named after them, e.g., Sarangpur named after Malek Sarang, Dariapur after Daria Khan, and Kalupur after Kalu. There were micro-neighborhoods within paras known as Pols. [5]

Pol settlement pattern has its origin from the rural villages of Northern Gujarat. This settlement is of khadki type. In a rural settlement, all families of one khadki belong to the same caste and also related by blood. However, in an urban setting, the khadki belongs to different castes. [6]

Source: Gaurav Gangwar, 23.02.2019

Figure 1. A 100 years old traditional Pol house. Heritage grading II-B by Ahmedabad Municipal Corporation.

Political authorities and wealthy merchants deliberately founded the walled city of Ahmedabad. From the very beginning, various castes were invited to settle in one ward, e.g., in handloom business, one caste made yarn, the other dyed it, third worked it into cloth, fourth painted it, fifth financed the various stages of work and ultimately sold the finished product. Castes and religious communities built their settlement as per their respective architectural tradition, and thus, the settlements resembled the rural pattern. [6]

The main difference between rural and urban khadki is the expansion of houses in an urban context. The rural houses consist of three parts (otala, parsal, and ordo) whereas, the urban houses consist of six parts. Out of six, two parts are in the front for strangers visiting the house for business. Three parts are at the back for residents. As

shown in Fig 2, the internal courtyard acts as a buffer between the front and the back for privacy. During the monsoon, the residents feel uncomfortable crossing the courtyard, which is the only link between three parts at the back and the two parts at the front. So, the covered passageway was built in the next stage of development around a courtyard. The kitchen is also placed on one side of the courtyard so that smoke and exhaust can quickly dissipate. On the first floor, three parts at the back and two at the front are repeated, except verandah. With an increase in demand for space, houses were extended to three or four stories. Larger windows became a part of the first floor of the house to act as a vantage point from where residents observe the streets' events. These windows have carvings similar to North Indian temples. The khadki room on the ground floor connects directly to the street. Some businessmen, jewelers, wealthy textile merchants did not want to expose their business to a street onlooker, so they transferred their business activities on the first floor. They made this area accessible from streets, allowing visitors to enter without interfering with the household activities on the ground floor. [6]

Source: Gaurav Gangwar, 23.02.2019

Figure 2. Courtyard design of a traditional Pol house more than 250 years old. Heritage grading II-A by Ahmedabad Municipal Corporation.

In conclusion, traditional Pol houses, as shown in Fig 1 and Fig 2, have evolved through many centuries by trial and error method. The present Pol houses are similar to rural houses of Gujarat but identify themselves as Pol houses in the walled city of Ahmedabad only. Locals design the houses, and these houses share the same principles of design throughout the walled city of Ahmedabad, as discussed in 4.3.1 except minor variation in sizes, shapes, etc.

3.2. Neighborhood Design of Pol Houses

Source: Undergraduate research thesis - Keyur Vadodaria, School of Architecture.

Figure 3. Plan of neighborhood design of Pol houses

Source: Gaurav Gangwar, 22.02.2020

Figure 4. Gate of a neighborhood of Pol houses

Pol houses settlements are considered to be 300-400 years old. They have lesser frontage (approx. 4-8m) and more depth (approx. 15 m), allowing streets to have minimal length. As per the modern neighborhood concept, this is the best way to design. The streets are narrow (approx. 1-4 m), which is beneficial for the mutual shading concept in summers. It helps in avoiding heat in the street and the house. There is a concept of sharing walls in Pol houses, which is very economical. The Pol houses rarely have front and rear open space, and the courtyard is the only open space. It provides light and ventilation in the entire building. Pol houses neighborhoods have one of the highest population

densities. Initially, there was no provision of market and other facilities within the gate of pols. However, these markets later developed along with the main street due to people's needs.

Source: Gaurav Gangwar, 01.12.2018

Figure 5. Street view of neighborhood design of Pol houses

In her research paper, **Kanika Agarwal** describes that streets of the Pol remain shaded and create excellent outdoor comfort conditions. Observations during the survey of Ahmedabad Pols revealed that 72% of the respondents were feeling comfortable on outdoor streets even when the temperature was 31°C with minimal air movement. Steemers et al., 2004 stated that it is always preferred to have shaded streets as compared to exposed ones in a hot climate. [7]

The effect of orientation of the street on the cooling load was simulated. Observations revealed that the cooling load reduced by 10.5% on the ground floor for N-S street and 16% for E-W street. Similarly, the cooling load reduced to 9% for the first floor for N-S street and remained the same at 16% for the first floor for E-W street. Therefore, the conclusion suggests that E-W streets are more effective as compared to N-S streets. The width of the street determines the shaded area of the street. For 8-12 m wide streets, 70% area is shaded when the H/W ratio is 1.2 to 1.6 for all streets except E-W. Similarly, for 1-4 m wide streets, 90% area is shaded when the H/W ratio is 2.6 TO 5.7. As shown in Fig 5, the streets of pols are having street width of 1-4m, and hence, are 90% shaded to create outdoor comfort on

the street. [7]

The conclusion shows that neighborhood design plays a vital role in creating the unique design of Pol houses. The Pol consists of 40-45 houses with close-end streets and gates, as shown in Fig 4; this is still relevant because of the requirement of a gated community in the modern context. The streets and size of the house are so well determined to create narrow, short-length streets. As shown in Fig 5, these streets provide shade in summers, and the cool air from the street enters the houses. The length of the street offers an advantage by reducing commuting distances for residents of Pol houses.

3.3. Spatial Aspects of Design

3.3.1. Disposition of Functions

The functional components within Pol houses, as shown in Fig 7 are described below:

a) Otala (Verandah Outside):

There is a sitting space before entering the Pol house called “otala,” as shown in Fig 6. It is a raised platform that differentiates house space from the street. It is used for religious activities also. There is space for washing clothes and toilets on one side of the otala. These street-facing activities became obsolete with time and were shifted inside the house. Nevertheless, in a few houses, people are using the space for washing clothes as well as a toilet. [3,8-9]

Source: Gaurav Gangwar, 22.02.2020

Figure 6. Otala space of a typical Pol house

b) Bhaitak (Drawing Room):

After entering the house, there is a drawing area called “bhaitak,” where visitors to the house are supposed to sit in this area. Bhaitak opens towards the courtyard side. [3,8-9]

Source: Gaurav Gangwar

Figure 7. Ground floor plan of a typical Pol house

c) Chowk (Courtyard):

As per Vastupurush Mandala, it is a place for Brahma, meaning; a place for the void. The courtyard is referred to as Brahma Sthan. The courtyard is the main feature of Pol houses. All activities are performed around the courtyard, as shown in Fig 8. The design of the courtyard was such as to avoid direct sunlight in summers and allow sufficient light for all activities. The courtyard is a central space and designed according to ancient Vastupurush Mandala. The proportions of the courtyard have been designed to link with upper floors. The windows of the upper floors open towards the courtyard. The visual connection is also well established with upper floors through the courtyard. There is a water tank under the courtyard, which acts as a rainwater harvesting tank. The tank's opening is sometimes clearly visible in the courtyard or hidden in parsal. The courtyard area is slightly lower to allow rainwater collection. Earlier, the courtyard used to be open to the sky. However, in some cases, it is covered by fiber sheets or clothes during monsoon to avoid the rainwater. This area of the courtyard is now leveled with parsal and bhaitak for the effective use of space. [3,8-9]

Source: Gaurav Gangwar, 30.11.2018

Figure 8. Informal interaction in Courtyard of Pol house

d) Parsal (Family Lounge):

The courtyard has a direct link with the street in most cases. There is verandah around the courtyard, also called “parsal,” as shown in Fig 9. Earlier, the kitchen was placed in a corner, but later on, one side of parsal has been used for kitchen and toilet in most cases.

This parsal has remained on two sides in most cases and three sides in a rare occurrence, it is valuable space for most of the activities. The swing in Pol houses is an essential feature and always placed in parsal. The parsal around the courtyard usually has colonnade. [3,8-9]

Source: Gaurav Gangwar, 22.02.2020

Figure 9. Parsal space showing the swing and other furniture

e) Ordo (Bed Rooms or storage):

After parsal, there are one or two rooms called “ordo”. These rooms are mainly used as bedrooms or storage spaces for the house. These are dark rooms and do not have enough light and ventilation. [3,8-9]

3.3.2. Aesthetic Considerations

The ornamentation of façade and interiors was a common phenomenon in Indian architecture for ages. Jones Owen states that the Indian artist believes that “true beauty in ornamentation results from the repose which the mind experiences when – the eye, the intellect, and the affections are satisfied due to the absence of any wants.” [10]

Source: Gaurav Gangwar, 24.02.2020

Figure 10. Façade treatment with wooden carving

Socio-religious principles governed the wooden carving, as shown in Fig 10 in Pol houses. Furthermore, the carvings serve as a symbol of financial status for wealthy Gujaratis who decorate their residences and personal belongings. Three factors affected the placement of carving on the domestic built form. The first one was a practical consideration; beams that were bulky and difficult to hoist were generally left uncarved. The second factor was the need for display; the vital part of buildings such as frontage, courtyard, parsal, which formed the backdrop of social activities, were ornamented to a greater or lesser degree. The third one was symbolic aspects of ornamentation. The basic principle followed by carvers while ornamenting the built form was “to ornament construction; never to construct ornamentation.” The prominent characteristics were continuity and plenitude of the ornamentation. Similar or same objects or forms created the design. The design of the carving is such that when viewed from a distance, the main lines strike the eyes. As one approaches nearer, the details come into compositions. On closer inspection, one further observes the marvelous details on the carved surfaces of decorative forms. [10]

Source: Gaurav Gangwar, 24.02.2020

Figure 11. Detail of Ornamentation (Motif of elephant, leaves, etc.)

These ornamentations consist of a rich vocabulary of motifs and patterns, as shown in Fig 11. The motifs are pictographic and categorized into figural, natural, and geometric. Figural motifs can be divided into six types. The first type consists of subjects like animals and birds. The second one is a composite of mythical beasts (ihamriga) or animated animal forms such as Gajvyala or Garsada (part-elephant, part-tiger, part-bird) Asvyala (part horse, part tiger), Kinnara or Kinnari or Kinnara Rupaka (part-horse, part-human). The third type includes Gods and Goddesses, such as Sri Lakshmi, Sri Ganesh, etc. The fourth one covers celestial beings like Apsaras, Vidyadharas, and Gandharvas. The fifth category incorporates objects and symbols such as Kalasha, Mangal Chinha, etc. The sixth type has narratives, such as scenes of Krishna's legends. Natural motifs consist of flower, plant, foliage, or tree. The geometric motif consists of geometrical forms and simple shapes like triangles, squares, circles, and diamonds.[10]

The façade treatment is one of the criteria for heritage listing done by Ahmedabad Municipal Corporation. Grade II A buildings have a better front façade or façade treatment inside the courtyard or parsal than Grade III buildings.

3.4. Environmental Aspects of Design

M. Susan Ubbelohde and George Loisos, in the

research paper titled “The Ahmedabadi Pol House: Courtyard Strategies in a Hot-Dry/Hot-Humid Climate,” describes the thermal Behavior of Pol Houses in different seasons. [8]

Thermal behavior in summer (Mid-March to Mid-June):

The bioclimatic chart for Ahmedabad clearly shows that there is a need for thermal strategies in summer months from mid-March to June. Pol houses are well-sited; long walls of the house are common with no sun radiation exposure, and short walls facing the street are shaded due to the narrow street section. The wall facing streets are using wood as the primary material, which does not gain too much solar heat due to its low thermal capacity. The exceptionally designed chowk or courtyard cuts the solar radiation in summers due to its tall and narrow shape through mutual shading. In most houses, the interior elevation of the courtyard also has wooden detail, which further reduces solar heat gain. The rainwater harvesting tank is always under the courtyard, and the specially designed courtyard's floor tiles gain less heat. The washing of clothes and utensils are also significant activities in the courtyard and responsible for evaporative cooling. The windows of the courtyard's house are open at night to attract the cold wind and are closed during the day to minimize solar heat gain. Most of the time, the ground floor is used during the day because the upper floors are very hot due to maximum solar heat gain through roof and terraces. The upper floors offer a cool area to sleep at night, along with other activities. [8]

Thermal behavior in winter (Mid-September to Mid-March):

The upper floor in winter gets maximum solar radiation through roofs. The orientation of windows, facing the street mostly in the south direction, allows the sun's penetration inside the upper floors. The sizes of the courtyard are small, so the sun does not penetrate the ground floors during winter. However, the courtyard act as a shield to protect from cold winter winds. [8]

Thermal Behavior in Monsoon (Mid-June to Mid-September):

The temperature is not high as compared to summer but still sufficient to create an uncomfortable hot and humid condition. The warm and humid conditions during monsoon become problematic because the houses have a minimum opening, which does not allow air to circulate. The courtyard is not a very comfortable place in monsoon due to rain, and many residents try to cover the courtyard through plastic sheets. [8]

The thermal behavior of courtyard houses is excellent

during the summer. The houses are a little bit comfortable in winter, not due to design features, but because winters are not critical. The monsoon season is worst for the Pol houses, and residents face many problems in this season. [8]

Mihir Vakharia describes how the presence of courtyard affects thermal characteristics within a space. He did this in his Masters in Interior Architecture and Design thesis on the topic "Impact of Presence of Courtyard on Thermal Characteristics of Vernacular Residential Building: An Exploration in Hot-dry Vernacular Context of Ahmedabad" from CEPT University.

There are comparisons of various parameters of thermal characteristics of three Pol houses with courtyard and without courtyard by using Computational Fluid Dynamics. These houses are approximately 100 years old and three-storied structure in Moti Hamam ni Pol. The field data collection under various parameters such as relative humidity, air temperature, air velocity, globe temperature, and surface temperature happened in April 2012 for seven days. The weather data collection occurred between April 2012 to July 2012. [11]

The study revealed that the incidence of solar radiation on the rooftop is the primary source of heat responsible for raising the exterior surface temperature of the envelope. Due to this, other surfaces such as adjacent plot share walls and the narrow streets shade the front surfaces. The ground floor courtyard in all three houses is shaded throughout the day and acts as a ventilation shaft and hence improves the thermal environment. The presence of the courtyard also improves the relative humidity, indoor air quality, and natural lighting.

3.5. Behavioral Aspects of Design

a) Neighborhood level:

Harminder Singh, in a research paper titled "Pol House (Residential Cluster), Ahmedabad," describes mainly about the culture of Pol houses. [12]

The community within Pol is an administrator by one statue of Pol assembly known as "Pol Panch" in Gujarati. The residents of Pol are supposed to follow the rules and regulations made by this Pol assembly. Sometimes there is more than one Pol assembly for a larger size of Pol, but every Pol assembly has its leader known as "Panch" There are two types of membership council for Pol, one is for the owner, and another is for a tenant. The tenant can participate in functions but cannot take part in decision making or setting the rules. [12]

The Pol council's role is to regulate the conduct of the Pol-resident, framing the rules and expectations from the council, and punish those who violated them, provide necessary amenities such as common latrines, street lighting, sanitation, well for drinking water, a place for

community gatherings, maintain common properties like a temple, arranging utensils for large dinners, a common meeting place for large gatherings, arrangements of the temple, organize religious and social celebrations, enact and revise rules relating to rent' and sales of the house in the Pol. [12]

There is one security officer named "Poliyo" who used to watch the outsider entry and also guard the Pol in the night. He is allowed to perform the other duties for more income for his family, and his family takes care of his work in a day. His responsibilities include clamping down the shutter, opening the main gate at a definite time, watching over the Pol during night hours, checking that every House of the Pol is appropriately locked up at night, messenger on various occasions like marriage, death, birth, community dinner, etc. carrying out the instructions of the Pol council when it meets and organizes collective activities and programs, and distributing Datana - a small thin fresh stick of babul tree used for a toothbrush.[12]

There was a very vital role of young and children to watch the outsiders while playing outside, and women also play a role in social interaction in the meetings held in the afternoon as males used to go for work. There are many traditional and cultural festivals held in Pol and make very vibrant living in the Pol. [12]

Source: Gaurav Gangwar, 23.08.2019

Figure 12. Picture of Mohalla Mata outside the wall of one Pol house

The study concludes that Pol assembly and Poliyo play a very crucial role in maintaining the security, culture, and tradition within Pol. Everyone in the pole can participate in community activities in one way or another. The above social system has no longer in existence its true essence. Still, there are many practices prevalent such as worship of Mohalla Mata, notice board of Pols, festivals in Pols. There is a need to revive this social system with modifications to suit the present need of people, and Ahmedabad Municipal Corporation can play a vital role in establishing this social system again.

b) House level:

Neeta Lambe, Alpna Dongre describe the relationship between the spatial organization and social behavior in the traditional Pol houses of Ahmedabad. According to Hanson (1998), the house is not the list of activities or rooms. However, it is a pattern of spaces that are connected and sequenced. They tell which activities go together and which activities remain separated. The author has taken a sample of the three traditional Pol houses and used various techniques such as space syntax for spatial and behavior relationship, visual permeability, and visual fields by using visibility graph analysis and visual penetration of layout by Isovist. The Pol houses are mainly for a joint family where at least three generations are living together. Due to constraints, spaces have more flexibility and are used for different activities throughout the year. Also, gender has no role in spatial segregation and it is sequenced as per the use pattern.[9]

The house's linear structure depicts the social behavior, the front part is public, and the innermost parts are private spaces. The design of the courtyard is such that it acts as a separation of public and private spaces.[9]

The analysis of the J graph shows that two or more spaces are having an indirect relationship with each other. The spaces are more shallow and good for social interaction. The otala is the first level of depth, khadki is the second level of depth, and the ordo is placed much deeper.[9]

The analysis of the visibility graph and Isovist show that spaces are very well visually connected. A multi-direction view from the courtyard suggests that a low clustering coefficient and thus making space more permeable. The higher the indivisibility, the more social interaction takes place in space, hence the courtyard acts as a very social interactive space. The higher Isovist area from the courtyard view makes it more spacious, and deeper Isovist perimeter makes it more open in a plan.[9]

Therefore, the conclusion reveals that the hierarchy of space demarcates the various activity domains. At the same time, the multi-functionality of space dictated the flexibility of using patterns and ways of life. The courtyard is space for the highest level of social interaction due to its visibility and connectivity to other spaces.

3.6. Other Aspects of Design

3.6.1. Building Materials and Construction Techniques

The houses' walls built with large bricks, and the binding materials are a mixture of mud and cow dung or lime surkhi. The wood pieces have been placed in this wall at regular intervals to make them stronger and stable. The wall thickness of the upper floor is less than the ground floor. The columns and beams are of timber, and the column base is always stone. [13] The Pol houses are very old building structures, and it is observed that due to non-maintenance of these materials, they are deteriorating at a fast pace. All of the building materials used are

locally available and are sustainable.

Source: Gaurav Gangwar, 24.08.2019

Figure 13. Use of Timber in the post, beam, and ceiling of typical Pol house.

3.6.2. Rainwater Harvesting

Source: Gaurav Gangwar, 23.08.2019

Figure 14. Rainwater harvesting tank under the courtyard

Rainwater harvesting is essential in the Pol Houses of Ahmedabad. There are storage tanks known as "tanku" under the courtyard, and they may extend to the nearby area. There is a provision for the collection of rainwater on the roof through pipes. The rainwater is saved and utilized for the entire year. It is extracted through an opening placed in the covered area. The size of the tank depends on the roof terrace area. Typically, the water tank can store 25,000 to 50,000 liters of water during the

monsoon season. [14]

The residents of Pol houses have stopped using the rainwater harvesting system, and the storage tanks are full of mud and other materials. There are many houses still having tanks, but they are not using these for rainwater harvesting.

3.6.3. Earthquake Resistance

An earthquake produces a complex set of forces, and the forces generated in structure will depend on the seismicity of the area and response of the structure to these forces. The response will depend on the configuration of buildings (size and shape, its components) along with other factors. [13]

The Pol houses of Ahmedabad have survived in various earthquakes, and at the same time, the new buildings in the new city of Ahmedabad have damaged a lot. There might be various reasons for making these buildings earthquake resistance. [13]

As discussed in 4.2, the Pol houses have common walls and no open space left in between. Therefore, all houses were joined together to form a block, and all houses shake according to their natural period of vibrations; hammering action between adjoining houses may also take place. From an earthquake point of view, this might be a disadvantage in the design of Pol houses at the Neighborhood level. [13]

The Pol houses have plan layout with main parallel wall cross junction with other walls at a regular interval; these perpendicular walls act as shear walls in case of an earthquake. All walls are matching with respective floor layout, which is very good for earthquake resistance. The courtyard opening with not well integrated with the rest of the structure creates a weakness for earthquake resistance. The doors are not placed symmetrically in the wall due to traditional principles which weaken the structure for an earthquake. [13]

The building material plays a significant role in earthquake resistance structures. The timber used in Pol houses has a well-deserved reputation for earthquake resistance. This high strength to weight ratio of timber enhances the strength under short term loading like an earthquake. The timber is an organic material, and their cellulose fiber makes it very highly effective under the tensile stresses. The large flat bricks used in Pol houses are evenly placed over each other on a well-made surface to stabilize against overturning. The bonding material used for brickworks is mud and cow dung or lime; this weak mortar perhaps adequate for bonding and allows a certain degree of movement and plasticity in the total wall during earthquake forces. Stone is used for the base of columns or post and door frames. The posts are effectively connected at the top and bottom, and structure can rock in a to-and-fro motion reducing lateral forces. The building materials used in Pol houses are helpful in the earthquake resistance. [13]

As per the study “Analysis of the System of Construction in the Traditional Ahmedabad Houses: Query

in Seismic Resistance,” the Pol houses of Ahmedabad qualified to meet some codal provision of the earthquake and failed to other provision of code of earthquake. [13]

4. Conclusions

The Pol houses are designed very expertly at the neighborhood levels as well as the design of the individual home. This typology has survived for 300-400 years and, at present, struggling for its survival, post-global era. Pol houses' urban settlement is very compact; streets are narrow to create shade in summers, length of the street is very less for natural pedestrian movement, one Pol consists of 45-50 houses, so community interaction is effortless. The gate of Pol houses can still act as a security feature. The social system in Pol houses was unique, and needs to be revived to fulfill the needs of the present and future generations. The courtyard is the soul of Pol houses, and it not only providing thermal comfort but very good for spatial segregation and integration of spaces; most of the activities are happening in and around the courtyard for all seasons. The construction system and building materials used in these buildings are unique to make these buildings earthquake resistance buildings. The provision of rainwater harvesting is a demand of the present time in the scarcity of water, and this system should be revived again for people. The Pol houses are not only functional buildings as concluded above, but these are showcasing excellent form and aesthetics. It concludes that Pol houses are inheriting with unique design, but there is a need to analyze the working of the Pol houses in a modern context.

Acknowledgements

This work is the outcome of a Ph.D. in the architecture of the author. The author acknowledges the expert guidance of his Ph.D. Guide, Dr. Prabhjot Kaur. The author acknowledges the support of Punjab Technical University to provide access to excellent library resources and other infrastructural facilities.

The author acknowledges the support of all residents of Pol Houses for providing their valuable time in a survey conducted by the author.

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