DISASTER-RESILIENT SETTLEMENT; A CASE STUDY OF A HERITAGE FISHING VILLAGE IN PENTHAKATA, ODISHA

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Abstract. Disaster resilience plays a critical role in assisting communities to recover from disasters and overcome challenges in the aftermath of such events. The resilience of coastlines is essential to withstand shocks caused by cyclones independently of the community, to adapt and rebuild more effectively following cyclones. This is currently the biggest challenge on the eastern coasts of India where Penthakata, the case study area, is located. Tropical cyclones can never be prevented; hence the need is to create and adopt cyclone-resilient techniques the in the community to build back and restore. Penthakata is the largest fishing village near the high tide line of the coastal plain of Puri district in Odisha where heritage fishing technique is practised. Despite a sizable business opportunity, it cannot prosper because of the tropical cyclones. The settlement needs to be reorganized, responding appropriately to its socio-economic and cultural requirements. The primary objective of this paper is to assess disaster resilience strategies applicable in such situations, as well as suggest suitable design interventions to redevelop the village with cyclone-resilient planning and built structures. A mixed methodology for data analysis was used in the primary survey and secondary literature review, along with consideration of future prospects.

Key words: self-sustainable, vernacular materials, intangible heritage, eastern coasts

1. Introduction

Tropical cyclones are a type of natural disaster originating from the warm tropical oceans and are characterized by low atmospheric pressure, high winds and heavy rainfall (Oliver, 2005). The temperature of the surface of the Bay of Bengal and the atmospheric humidity are key factors responsible for forming cyclones on the eastern coasts. In the current changing climatic scenario, the frequency of severe cyclonic storms has been increasing in the Indian sub-continent, with the eastern coasts being more vulnerable than the western coasts (Charabi and Al-Hatrushi, 2010). In India, the ratio of cyclones on the eastern coasts is 4:1 as compared to the western coasts (Babu, 2022). The peak months of major tropical cyclones are from June to November. Nowadays because of the rising temperature, the month of May has

also become more prone to tropical cyclones. On average, Indian coasts experience at least five to six tropical cyclones every year, where two out of three are classified as severe cyclonic storms.

Table 1. List of severe cyclonic storms faced by Odisha's coast from 2013 to 2021 (Source: Sarkhel *et al.,* 2019).

Year	Cyclonic Storms	Wind Speed (in kilometres per hour)
2013	Phailin	250
2014	Hudhud	180
2018	Titli	165
2019	Fani	205
2020	Amphan	185
2021	Yaas	155

Cyclones are recognized not as events, but as hazards, having the potential to cause extensive material and physical harm (Cutter *et al.,* 2000; Paul, 2020). Over the last decade, Odisha has faced at least one severe cyclonic storm yearly (see Table 1) (Tamuly and Mukhopadhyay, 2022). The low-lying coastal and offshore islands have experienced severe cyclonic storms and storm surges during the last five decades, and the low-lying coastal and offshore islands have experienced a tragic history of fifty severe cyclones and storm surges (Mohanty *et al.,* 2022; Fanchiotti, 2020).

2. Aim

This research aims to redevelop Penthakata, an existing heritage fisherman community, as a cyclone-resilient settlement, keeping the heritage values intact.

3. Scope and objective

To understand the local adaptation and housing practices of Penthakata as a fishing community. To understand and protect the intangible heritage, lives and livelihood of Penthakata to create a safe livable space. To create new standards in cyclone resilient community housing by providing good quality housing with basic infrastructure and keeping resilient design in focus.

4. Methodology

This study is descriptive and exploratory. It emphasizes the approach toward disaster resilience of Penthakata.

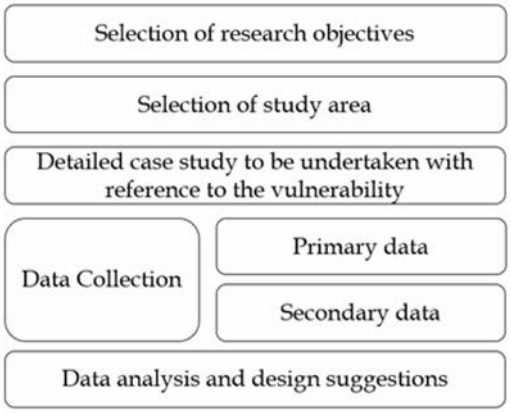

Fig. 1. Flow chart of research methodology (Source: Authors).

A literature review and a field survey were conducted (refer to Fig. 1). The present fieldwork contains a detailed database and information. The primary data was collected from the residents of Penthakata. The data was collected directly from the 180 respondents of the Penthakata through a comprehensive interview and questionnaire. Measurement and the secondary data from books, journals, thesis etc. Both quantitative and qualitative data were analyzed and performed and are shown in the suggested design strategies.

5. Data collection

5.1. Literature survey

Penthakata is an unplanned fishermen's slum in the northern part of Puri town with fishermen from the state of Andhra Pradesh residing in temporary shelters

during the fishing period in the year in the 1950s. It is located in ward number 26 of Puri municipality (refer to Fig. 2). The community is situated in-between Chakratirtha road and the Bay of Bengal. The fishing community has two parts i.e., Penthakata 'A' and Penthakata 'B'. It is situated over unauthorized revenue land.

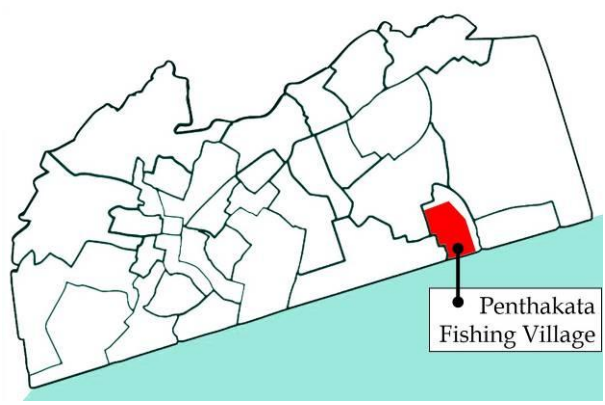

Fig. 2. Location of the study area 'Penthakata' in Puri municipality ward map (Source: Devkota, 2019).

The coastline of the Puri district is the longest in Odisha, measuring around 155 kilometres laterally to the Bay of Bengal (Ramesh *et al*., 2011). Penthakata, Odisha's largest unplanned traditional fishing village, is situated here, stretched over an area of 1.42 square kilometres beside Puri's northern coastline and 40 metres away from the high tide line. The village population density is very high and is housed by a significant migrant population from the neighbouring state of Andhra Pradesh. The migrants are mainly seasonal labourers who have settled here to improve their occupation and economy (Panda and Mishra, 2020). The economic status is poor and unstable (Balasubramanian, 2001; Chakraborty, 2016). The migrations in the same patch of land over the years have changed the patterns of livelihood of the pre-existing fishing communities of this coastal village. The fishermen operate log rafts, nava and bar boats from the open beach. All boats are traditionally made boats. Motorized boats are not allowed in the Puri because of the narrow continental shelf. This place has been a victim of many cyclones with continuing impacts like the 2019 cyclone Fani, a rare summer severe cyclonic storm (Babu, 2022; Salagrama, 2006).

5.2. Disaster resilient techniques

The disaster-resilient techniques are the approaches that help the community to flourish even in the situation of disaster. The techniques help the community in easy anticipate, survive and self-recover during the time of disaster. Some ways are planting mangrove forests along the coasts and around the house to act as a windbreaker and reduce the flow of the wind (refer to Fig. 3).

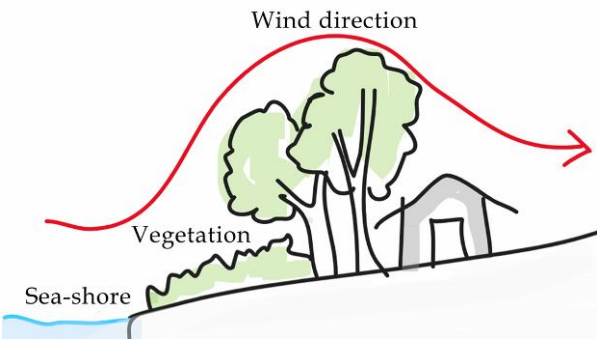

Fig. 1. Trees plantation along the coasts (Source: Authors).

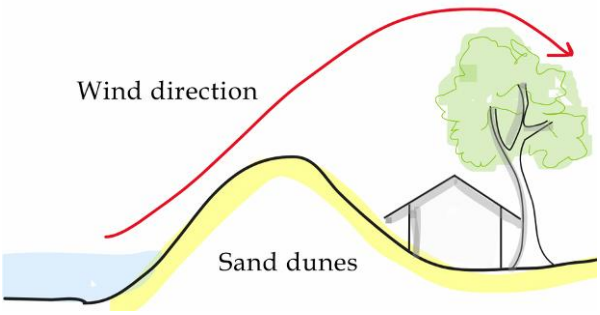

Fig. 2. Use of natural dunes as a natural barrier against wind and storm (Source: Authors).

Naturally made coastal dunes also act as a natural barrier against wind and waves (refer to Fig. 4).

The zigzag cluster planning of the community reduces the wind movement refer to Fig. 5). The simple, compact,

symmetrical building form i.e., rectangular allows easy wind movement around them.

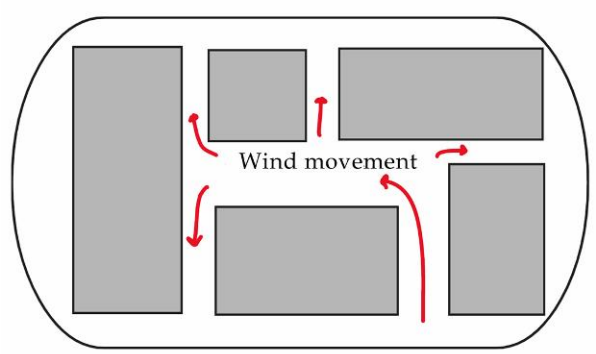

Fig. 5. Zigzag cluster planning of streets (Source: Authors).

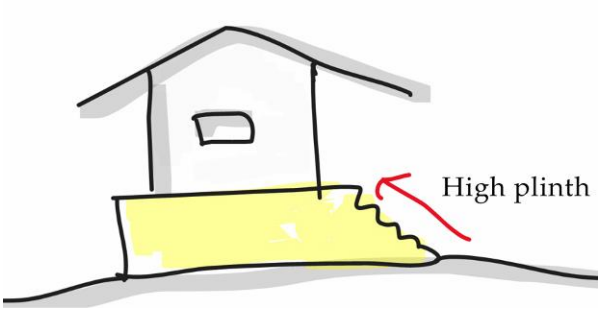

Fig. 6. High plinth or raised earth mounds (Source: Authors).

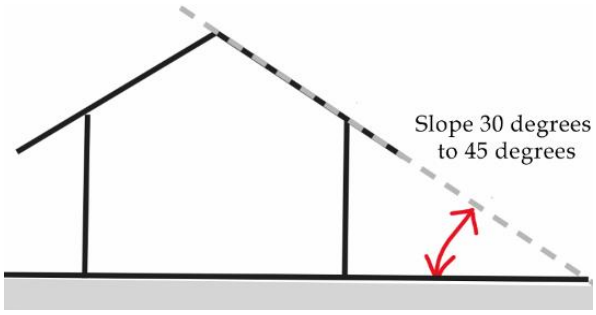

Fig. 7. The roof slope of 30 to 45 degrees prevents it from being uplifted (Source: Authors).

Community planning, building form and orientation are the primary methods to make any cyclone-prone community resilient. Construction of building plinth level higher than the existing surrounding area to reduce the risk of storm surge (refer to Fig. 6). The slope of the roof should be constructed at an angle of 30 to 45 degrees to prevent it from being lifted off by the wind (refer to Fig. 7). It is a common misconception that the loss of cladding relieves the burden on building frameworks. It has been observed that there are several circumstances in which the opposite is true. In these circumstances, the wind loads on the structural frame are increased substantially as a result of cladding loss. Usually, wooden frames are weak at the joints. Thus, economising on minor items (bolts) has led to the overall failure of the major items (columns, beams and rafters).

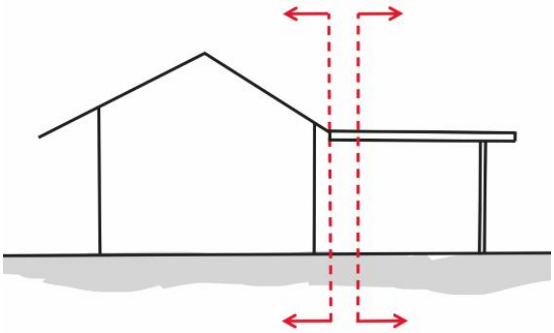

Fig. 8. Wide roof overhangs should be avoided. (Source: Authors).

Wide roof overhangs should be avoided and additional spaces like the verandah structure should be constructed separately from the main house roof (refer to Fig. 8). Sometimes, cyclone winds can lift buildings completely off the ground. Unlike designing for gravity loads, the heavier the building, the larger (or heavier) the foundation must be in order to withstand cyclones. Unreinforced masonry frequently collapses during powerful cyclones. Most at risk are parapets with cantilevers. But so too are safe columns and walls supported by ring beams.

The raft foundation is recommended to support the building and easily transfer its weight to the ground in the coastal areas. It is also economical and easy to construct. Foundation, walls and roofs need to be fixed firmly to protect dwelling units (refer to Fig. 9).

Table 2. List of survey questions (Source: Authors).

Total number of respondents: 180	Male: 97	Female: 83
How long you have been staying here in Penthakata?	From Birth	
How many times have you experienced a cyclone in your lifetime?	5	
How many times have you had to evacuate your home?	4	
How many people do you have living with you?	5	
Does any of your family members have special needs (mobility challenges)?	23 / 180	
Who is the main earner in the household?	Male Person	
What is the average income in your household in a month (For example the combined income)?	20,000 to 100,000 per annum	
What is the area of work of the main earner?	Fishing	
How do you sustain your livelihood at the time of off-season / disaster?	Same as before	
Your house was destroyed or badly damaged.	Destroyed 75%	
What degree of damage to the house during last year's cyclonic storm?	Substantial failure of walls and roof	
Type of house: Single storey Size of the house (in square feet): 150-200 sq. ft. Roof type: One side slope, two side slopes and hipped roof Roof material: Tarpaulin and asbestos Material of the walls: Brick wall Type of flooring of the house: Cement flooring Does the house have a plinth? If yes, the height of the plinth: Yes and 2 feet Toilet size: Attached (3 feet X 4 feet)		
Number and the size of streets abutting the houses?	One side is open and narrow	
What is the general floodwater level in this locality during a cyclone?	3 feet	
What were the ways to disseminate warnings to the community?	Volunteers, speakers, radio and television	

5.3. Case study (Penthakata)

A sample survey of 180 residents of Penthakata has been taken. The following (Table 2) shows the detailed questionnaire.

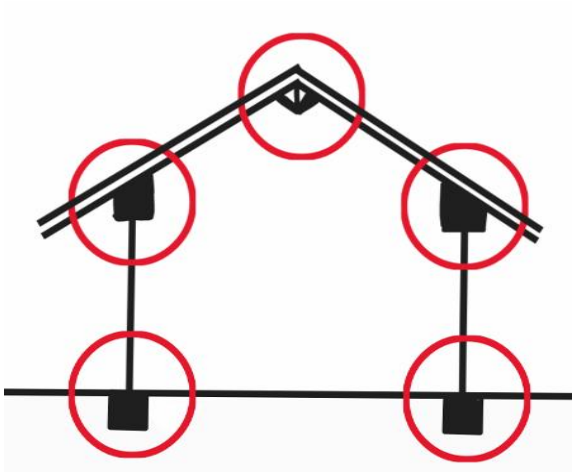

Fig. 9. Foundation, walls and roof structure must be firmly fixed (Source: Authors).

6. Data analysis and inferences

Penthakata village is a highly disaster / cyclone-prone area. Housing is an important asset of life which is the main problem of the community. Based on the type of construction only 8 percent of the fishermen had permanent (pucca and semi-pucca) houses; another 16 percent had the semi-permanent house funded by the scheme 'Indira Awas Yojana', while the large majority of over 80 percent of people living in non-permanent (kutcha) houses (refer to Fig. 10). However, 99% of houses are structurally weak (refer to Fig. 11).

Fig. 10. Typical house of Penthakata (Source: Authors).

During cyclones, the loss of roofs has triggered the destruction of unreinforced

masonry walls. The area of each house is less than 25 square meters. Each house consists of one bedroom, kitchen, toilet and a small verandah for daily activities. There is a lack of basic amenities and sanitation. The village is densely populated with a haphazard way of planning. Coastal erosion is also a major problem and there is no scope for further development of the community (Mishra *et al.,* 2021). The narrow streets are used as pedestrian pathways (refer to Fig. 12).

Fig. 11. Cyclone affected the houses of Penthakata (Source: Authors).

Fig. 12. The street pattern of Penthakata (Source: Authors).

The villagers will be living with the cyclone so some disaster risk reduction plans should be formulated like awareness programs and the implementation of cyclone-proof local vernacular construction techniques (Chhotray and Few, 2012; Stewart and Li, 2010). Post-disaster community engagement is important for easy recovery (Marsh *et al*., 2003; Djalante *et al.,* 2021). Over the past 20 years, the community had participated in all cyclones resulting in zero mortality rate.

7. Suggested design strategies

The incremental housing types are proposed for better sustenance of the dwellers against a cyclone. Considering the heritage value, and connecting the past with the future, cyclone-resilient houses for a decent quality of life with locally available materials (Pal, 2021). The improvement of local building materials and techniques with advanced practices for better resistance during a disaster (Das and Mandala, 2020). Housing affordability is required along a variety of interlocked cultural and social values important to the fishermen's livelihoods at both personal and community levels (Doloi and Donovan, 2019).

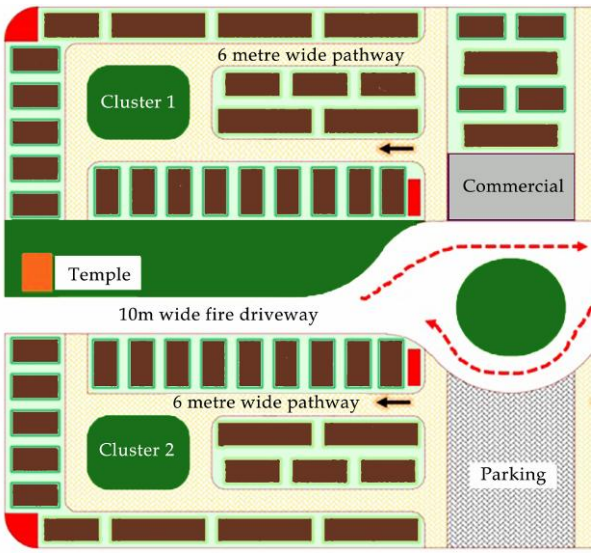

Fig. 13. Proposed typical cluster layout showing houses, driveways and movements (Source: Authors).

The proposed cluster (refer to Fig. 13) is rearranged in such a way that it could help in easy service and fire tender during the evacuation, disaster and recovery. All structures are easily accessible to roads for easy evacuation during the disaster (Murthy, 2007). The number of units in each cluster is 22. Each unit is a space provided for a minimum of six and a maximum of eight dwelling units (refer to Fig. 14). The orientation of units in a cluster is in such a way that it would obstruct wind movement. It would allow the wind to change its direction to reduce the wind speed with travel distance.

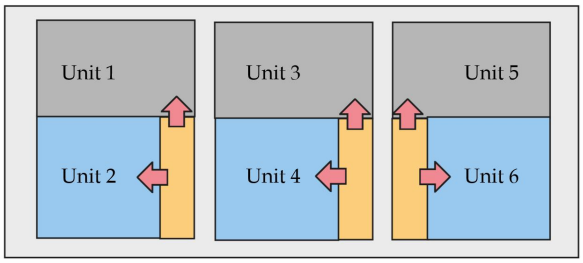

Fig. 14. Proposed typical unit layout showing dwelling units (Source: Authors).

All dwelling unit walls are shared with the neighbouring unit to minimize risk during the disaster structurally and economically. The wall vertical reinforcement is also necessary for better resistance during high wind speeds. Another key need is to save the roofs of coastal houses from high cyclonic wind by strengthening the connection of the roof with the structural columns and beams.

Four layered roofing systems (refer Fig. 15). It is the combination of the split bamboo mesh of 6-inch height placed centre-to-centre, a tarpaulin sheet of GSM (Grams per square metre) 70, and a local palm thatch layer tied with a waste fishnet at the top. The roof's hip pitch degrees (Keote *et al*., 2015; Ahamed *et al*., 2012). Coconut shell concrete for road paving and flooring for the flooring as it is abundantly available in the coastal belts. Coconut trunk as the post and lintel. The selection of adequate fastening devices, adequate sheet thickness and sufficient frequencies of fasteners in the known areas of greater wind suction is important. Reinforced masonry needs to be mandatory in cyclone-prone areas (Rashid and Paul, 2016). Walls need to be braced by ring beams and columns to give extra strength. Cantilevers and parapets need to be avoided. Local species plantations i.e., mango, cashew nut and naturally created dunes along the coasts prevent the direct hit of wind on the settlement.

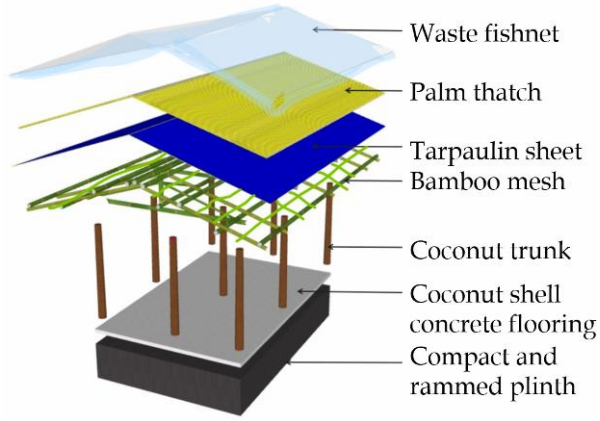

Fig. 15. Proposed four-layered roofing system. (Source: Authors).

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