46 Assessing the Planning and Design of Households for Resilience to Natural Hazards—A Case of Pune City, India

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Abstract

Cities are growing enormously globally, witnessing the technological changes and absorbing the migrating populations. People choose cities in aspiration of better life and livelihoods. Urban communities are more vulnerable to natural hazards especially the urban poor. In this study we assess the residential buildings of 400 households of different income groups in Pune city, of Maharashtra State of India. Various design and planning parameters are selected to understand the resilience of the household to prevent and mitigate the risks of natural hazards, earthquakes and floods. A questionnaire survey was conducted to understand the perception of the household. The results were evaluated with the data from field visits and key stakeholders interviews. The study reveals, in the low income communities, the planning and design aspect of the buildings is of least priority. The study further reveals most of the household wherein the design and planning elements are compromised are vulnerable to the impacts of natural hazards. The study concludes architecture thus is a key to prevent and mitigate the risks and enhance resilience to natural hazards.

Keywords

Architecture · Resilience · Planning and design · Community resilience · Natural hazards

46.1 Introduction

Cities are growing enormously globally, witnessing the technological changes and absorbing the migrating populations. People choose cities in aspiration of better life and livelihoods (Godschalk 2003). The growing densities in the urban areas are attracting disaster risk especially with the threats of climate change lingering around. The sudden wet spells are causing flooding situations threating the life and property of citizens (Singh et al. 2014). Cities thus are under threats of disasters waiting to happen. The Sendai Framework for Disaster Risk Reduction (SFDRR) prioritizes the understanding of disaster risks to make informed decisions on planning and development of the cities, further the investments made in risk reduction will give long term benefits to cities in enhancing and maintaining resilience.

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The growing populations of the cities need housing and built infrastructure for their sustenance. (Mouratidis 2021) The stress on land value makes housing unaffordable to the poor sections of population (Turok et al. 2022). Sustainable Development Goal (SDG) 11 promotes providing adequate shelter for all. City administrations are trying hard to generate enough housing stock to accommodate populations, increasing the densities of built structures. Yet the poor and migrant population finds it difficult to afford safe shelters forcing them to settle in risk prone areas or unsafe built structures (Gandhi 2012). Spatial planning of the urban areas needs to stress on landuse planning to reduce the exposure to disaster risks from natural hazards like floods (Fleischhauer 2008). The spatial planning approach adopted by city administration is 'top down approach' (Cutter et al. 2016; Li et al. 2016; Yoon et al. 2016; Mavhura et al. 2021). In literature there exists various qualitative and quantitative frameworks to assess resilience in top down approach (Joerin et al. 2014; Wang et al. 2019; Mohanty et al. 2020) however in practice bottom up approach is needed to understand the ground realities. Disaster risk arises from the combination of hazard and vulnerability (Rus et al. 2018). The built environment influences the scale of vulnerability especially to the spatially relevant disasters like earthquakes and floods (Leon et al. 2019). Resilient communities are prepared communities to face and absorb the hazard risks (Bozza et al. 2015). The resilience of the city thus is depends on how resilient is its built environment to absorb the shocks of disasters (Parker 2020; Shamout et al. 2021). The urban poor communities, wherein the architecture is evolved through community artisans, disaster safety could be enhanced to bring in resilience 'leaving no one behind' in the safety net. Architecture plays an important role in creating safe infrastructure and facilities (Bejtullahu 2017). Architecture can help in evolving an innovative approach to understand the disaster risk complexities by providing newer ways to build physical and socio-economic resilience of the vulnerable communities (Charlesworth and Fien 2022). It encompasses the buildings designed by architects and building designs evolved through community artisans. It also encompasses retrofitting and adaptation of the structures already built. Architecture can play vital role in strengthening the urban ecosystem by shaping the built environment (Chansomsak and Vale 2010). This paper thus attempts to study the disaster safety of the buildings and its occupants through various architectural components of built structure through the household's perspective. The aim is to understand how resilience to natural hazards is influenced by architecture of buildings in different socio-economic groups.

46.2 Material and Methods

46.2.1 Study Area

The city of Pune is situated on the confluence of rivers 'Mula and Mutha'. It is the 8th largest city in the country, 2nd largest in the state of Maharashtra with a population of 3.9 million. The demographic study of the city reveals, about 62% of population is under age of 30 and with 86% literacy rate of the city. The availability of various livelihood options makes the city attractive for migrants. The city has historical value, few decades ago was the city was calm, favored by retired people to settle down. Since last three decades it's a vibrant and growing city with boom in sectors like, industrial, education, real estate and Information Technology. The housing typology has changed since then, from individual houses to multistory apartment building and 40% population staying in informal settlements. Figure 46.2 shows the households of low income groups, while Fig. 46.3 shows the housing typology of different income groups in the study area (Fig. 46.1).

The city lays in zone III of earthquake zone with susceptibility of 4–7 Richter scale earthquakes though there is no history of earthquakes. However the city has experienced tremors during Latur earthquake of 1993. Pune is exposed to both riverine flooding and urban flooding. The riverine flooding is caused by the release of water

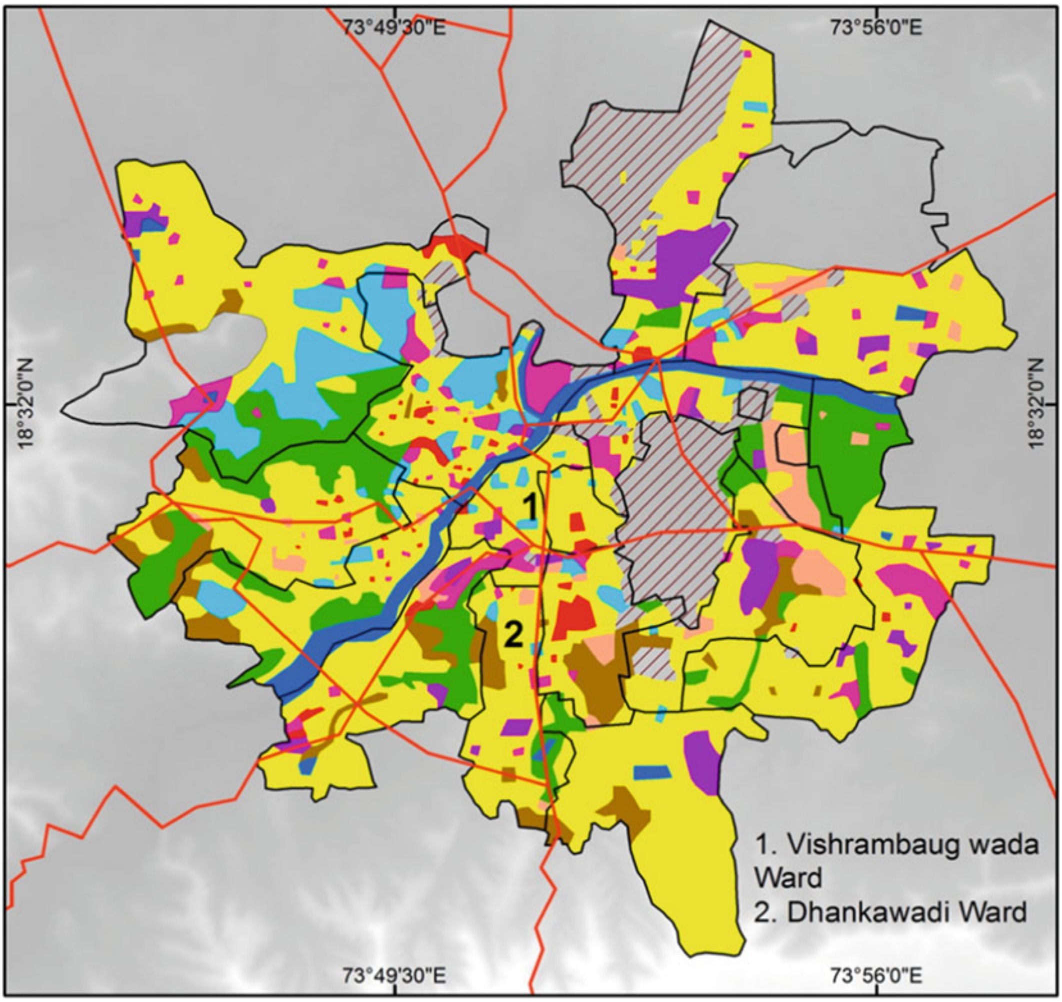

Fig. 46.1 Map of Pune city showing location of 2 wards of study area. Source: Pune Municipal Corporation

into the river by 5 upstream dams and urban flooding due to heavy precipitation during monsoon months and lack of surface drainage system quantitatively. Administratively the city is divided into 15 wards out of which 2 wards are selected for the study namely 'Kasbapeth Vishrambaug wada ward' and 'Dhankawadi-Sahakarnagar ward'. The 'Regional Disaster Management Plan of Pune 2015' concludes these two wards of Pune city have high risk exposure.

Kasbapeth Vishrambaug wada ward is the central and oldest part of the city and is called 'Gaothan area' (city center) in the development plan, located on the banks of river Mutha. It has high density of people and buildings, being the city center. The population of the ward is composed of different social and economic status. The slum settlements are located in low lying areas and encroached river banks. The building regulations are different to accommodate high density, hence the side margins for buildings are relaxed and buildings can have only front and rear margins. Central open ducts called 'chowks' are used for natural light and ventilation to the interior parts of the buildings.

Dhankawadi village was added to the Municipal corporation limits in 1997 and then combined with Sahakarnagar ward. The built environment of the ward changed since then with rapid development of apartment buildings mostly

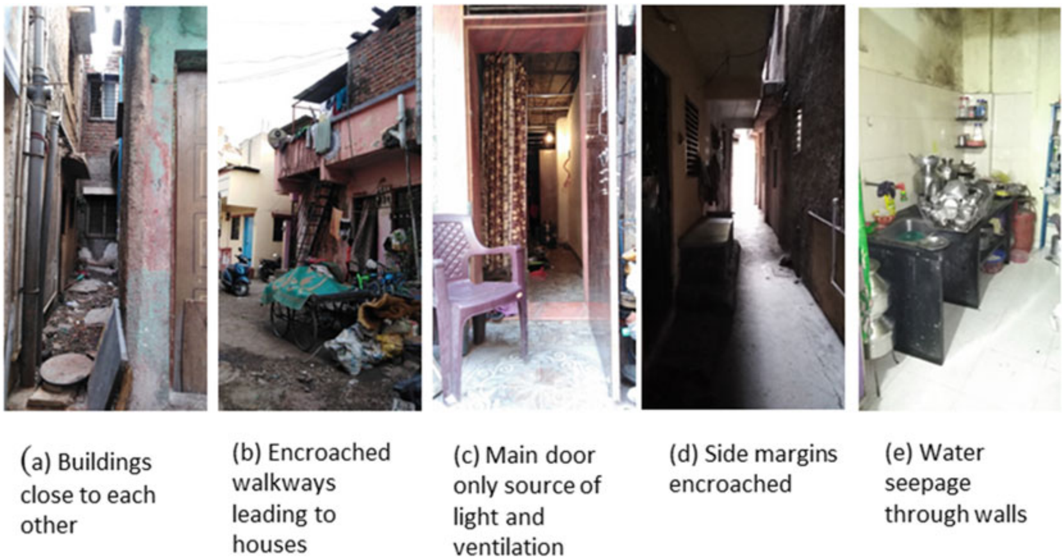

Fig. 46.2 Households of low income communities

Fig. 46.3 Housing typology of different income groups

non-conforming to building regulations. The terrain of the ward is hilly and comprises of water bodies and river tributaries. The built environment hence faces the challenges of unscientific construction practices of buildings, roads and infrastructural services like water supply and drainage systems. The dense built pockets of the ward have accessibility issues.

46.2.2 Selection of Indicators

The study adopts the planning and design components of buildings based on the guidelines given by National disaster Management Authority of India for earthquake and flood safety (NDMA 2016). The indicators selected are grouped in 3 sections, architectural, structural

Table 46.1 Planning and design components and its description

Components	Indicators	Description
Architectural	Location	Exposure to floods, water logging, densely populated, risky hill slopes, reclaimed lands, inside blue line of rivers
	Proportions and geometry	Earthquakes guidelines as per National Building Code (NBC)
		Length and breadth ratio, height, shape and size of buildings
	Building envelope	Earthquakes guidelines as per National Building Code (NBC) envelope material and elements like railings
	Openings for doors and windows	Natural light and ventilation
		No dependency on artificial and mechanical systems for light and ventilation as per NBC
	Passageways for safe evacuation	Clear and hurdle free passages for evacuation no furniture items, planters, vehicles parked etc. in passageways
	Open spaces around buildings	Building margins on all sides of building as per building regulations including gardens, play areas and open parking lots
	Basements	Single or double basement used for parking, water storage tanks, sewage treatment plants etc.
	Roof top terraces and refuge floors	Availability of roof top terraces for evacuation
		Refuge floor for building height above 21 m as per building regulations
Structural	Construction material and technology	As per Indian Standard (IS) Codes
	Earthquake resistant designs	As per Indian Standard (IS) Codes for earthquake resistance
Safety	Firefighting system	Availability of firefighting system as per building regulations
	Electrical safety system	Availability of electrical safety system as per building regulations
	Maintenance of buildings	Repairs, refurbishment, retrofitting to address the issues of leakages, cracks, plumbing, drainage and electrical services
	Accessibility of critical services	Width of access roads more than 4.5 m for a fire engine to pass accessibility of ambulances

and safety components. Table 46.1 shows the indicators and its descriptions. These indicators influence the safety of the buildings and its occupants for earthquake and flood hazards. These indicators are inherently the prevention and mitigation measures when integrated in planning and design of buildings, for enhancing resilience to natural hazards.

46.2.3 Methods

The study method adopted was questionnaire survey of 400 households, field visits and interviews of 10 key stakeholders. 4 groups of 50 households of different income categories were identified from each ward. Table 46.2 shows the different income groups. Table 46.3 presents the key stakeholders. The participants were adult male and females in age group of 25–65 residing in the locality since past 25 years. The households were part of different residential apartment buildings in all the categories expect the very low income group, which mostly comprises of slum settlements. House hold data was collected from the participants through a questionnaire survey. The questionnaire comprised of open ended questions and sub-questions to understand their perception on the safety of their apartment buildings and individual households. Field visit were conducted to compare the data collected through questionnaires. The data received

Table 46.2 Different income groups and description

Income groups	Name of group	Description
High income group	*A*	Households residing in residential property worth 2 Cr (2,44,356 USD) and above
Middle income group	*B*	Households residing in residential property worth 80 lakhs (97,740 USD) and above
Low income group	*C*	Households residing in residential property worth 30 lakh (36,652 USD) upto above
Very low income group	*D*	Households residing in residential property worth 3 lakh (3665 USD) and below

through questionnaires and field visits was further validated from key stakeholders through face to face interviews. The aggregated data was analyzed to understand the vulnerabilities of each household with Likert scoring and its impact on resilience whether positive or negative.

46.3 Results and Discussion

The vulnerabilities of the households due to the planning and design components of their residential buildings are mapped and presented in Table 46.4. The participants acknowledge their built environment vulnerability and how it can expose them to risk in emergency scenario. This section presents the results of the study followed by the discussion.

46.3.1 Architectural Components

46.3.1.1 Location

The participants of the *A* and *B* group reside in comparatively safe locations which are away from river banks and hills with balance densities, resulting in low risk to earthquakes and floods, while the participants of group *C* reside dense built environment and on hill slopes and in proximity to river tributaries, locations with risk exposure to both earthquakes and floods resulting in high risk. The participants of group *D* reside in low lying areas and on banks of river with high exposure to floods resulting in very high risk. The overall impact of the indicators results in negative impact on resilience.

The participants of group *A* and *B* communities are economically privileged to choose the comparatively, safe locations for their residential occupancy. The location of group *C* communities is dense arrangement of buildings and comparatively risky locations like hill slopes or reclaimed lands, especially in Dhankawadi-Sahakarnagar ward. The group *D* communities in both the wards are located in low lying areas and near the river banks, which makes them highly vulnerable to flooding every year.

46.3.1.2 Proportion and Geometry of Buildings

The proportion and geometry of the buildings was a choice-based question with options depicting shapes and ratios. Accordingly the

Table 46.3 Key stakeholders and their description

Stakeholders	Nos.	Description
Architects	2	Architects practicing in the study areas for last 25 years
Structural engineers	2	Practicing engineers in the study area with last 15 years
Contractors	2	Constructed more than 50 buildings in study area
NGO representatives	2	NGO's working in study area
Community volunteers	2	Representatives of the group *C* and *D*

Table 46.4 Vulnerability of households to planning and design components

Components and Indicators	Responses of household groups				Aggregation of Vulnerability	Impact on Resilience
	A	B	C	D		
Architectural						
Location	LOW	LOW	HIGH	VERY HIGH	HIGH	NEGATIVE
Proportions & Geometry of Buildings	MEDIUM	MEDIUM	HIGH	HIGH	HIGH	NEGATIVE
Envelope Elements	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	POSITIVE
Openings for doors and windows	LOW	LOW	HIGH	VERY HIGH	HIGH	NEGATIVE
Passageways for safe evacuation	LOW	MEDIUM	VERY HIGH	VERY HIGH	VERY HIGH	NEGATIVE
Open Spaces around buildings	LOW	LOW	HIGH	HIGH	MEDIUM	POSITIVE
Basements	MEDIUM	HIGH	LOW	LOW	MEDIUM	POSITIVE
Roof top terraces	LOW	LOW	MEDIUM	VERY HIGH	MEDIUM	POSITIVE
Structural						
Construction material of buildings	LOW	LOW	VERY HIGH	HIGH	HIGH	NEGATIVE
Earthquake resistant designs	LOW	LOW	VERY HIGH	VERY HIGH	HIGH	NEGATIVE
Safety						
Fire Fighting System	MEDIUM	HIGH	VERY HIGH	VERY HIGH	VERY HIGH	NEGATIVE
Electrical Safety System & equipments	MEDIUM	MEDIUM	VERY HIGH	VERY HIGH	VERY HIGH	NEGATIVE
Maintenance of Buildings	MEDIUM	MEDIUM	HIGH	HIGH	HIGH	NEGATIVE
Accessibility of critical services	LOW	LOW	VERY HIGH	VERY HIGH	HIGH	NEGATIVE

option chosen by *A* and *B* group participants indicate the risk as medium to this indicator, while the *C* and *D* group participants indicated high risk to this indicator. The group *D* participants were hesitant to choose the option however, as they were not very sure about the proportion and geometry of their houses. The overall impact on resilience is negative for this indicator.

The National Building Code (NBC) of India specifies the proportions and geometry for the architectural designs of buildings for earthquake resistance, though it is not mandatory to adopt as per building regulations. The proportions and geometry is guided by the size and shape of the plot and the floor space ratio. The *A* and *B* group communities can afford to choose the buildings which are designed by architects as per building regulations, which may still not be appropriate for earthquake and flood resistance, hence the risk to such buildings is medium. The *C* and *D* group communities reside in buildings which are majorly evolved as per the availability of space and does not necessarily follow building regulations hence the architecture may not provide and resistance to resulting in high risk.

46.3.1.3 Building Envelope

The question was presented as various options of building envelope including construction material and elements, conventionally used in the city like glass and concrete, plastered brick masonry; unplaster brick masonry, tin sheets. The participants of group *A* and *B* choose similar envelopes composed of materials like concrete and brick masonry, envelopes that are structurally sound to provide safety against natural hazards resulting in medium risk. The participants of group *C* are familiar with the plastered brick masonry envelope while participants of group *D* are accustomed to unplaster brick masonry and tin sheets resulting in medium risk.

The design of the building envelope is attributed to the architecture design and aesthetics of the building. The most conventional building envelope uses brick masonry and glass windows with use various materials for facades though less likely in residential buildings. Envelope elements are limited to handrails, canopies and grills conventionally. The national building code (NBC) specifies guidelines for earthquake resistant designs, for the detailing and joinery of material and elements of the envelope. This can warranty safety of people while evacuating in the emergency situations. The interview with architects and developers confirms that there is lack of awareness in the fraternity on NBC guidelines. This makes all the occupants at an equal risk.

46.3.1.4 Openings for Doors and Windows

The question was formulated to understand the sufficiency of openings for natural light and ventilation and was formulated in comparison with the requirement of artificial light and mechanical ventilation inside the houses. The group *A* participants choose to opt for the availability of sufficient natural light and ventilation, but added air conditioning system preferred for ventilation indicating low risk. The group *B* participants opted availability of natural light and natural ventilation with the requirement of air conditioning system in peak summers indicating low risk. The group *C* participants opted for sufficiency of windows but dependency on artificial light and mechanical ventilation indicating high risk. The *D* participants opted for insufficiency of windows and dependency on artificial light and ventilation indicating very high risk to this indicator. The overall impact on resilience for this indicator is negative.

The *A* and *B* group communities occupy buildings, designed for achieving natural light and ventilation, by maintaining appropriate distances in between buildings which is mandatory part of building regulations. The risk hence is low. The buildings occupied by the group *C* communities are located in densely built pockets in haphazard layouts and not necessarily abide the building regulations, wherein the proximity with other buildings compromises the quality of natural light and ventilation. The group *D* community housing is densely laid with only one face of the structure abutting the narrow passageway available for light and ventilation.

Moreover the windows have to be covered for privacy reasons. This makes them dependent on artificial light inside the houses continuously. The ventilation conditions inside the houses are poor which leads health issues as expressed by the participants.

46.3.1.5 Passageways for Safe Evacuation

The multiple choice question on this indicator required information on width of the passageways leading to houses, movement pattern and list of furniture accessories in the passageways. The group *A* participants choose the items laid out in the passage ways but the width of passageways is sufficient to provide safe access for evacuation in emergency scenarios indicating low risk similarly the group *B* participants indicate medium risk with decreased width of passageways. The group *C* and *D* participants added to list of items stored in passageways and further reduced widths of passageways which can create hindrances to fast evacuation in emergency scenarios, indicating very high risk to this indicator. The overall impact of the indicator on resilience is negative.

In the emergency scenarios like earthquakes and floods wherein fast evacuation is required having clear passageways is necessary. Culturally the houses need to have various items outside the house like shoes. It's a common phenomenon to have furniture accessories like shoe stands, planters, seats to be accommodated in passageways leading to houses. The group *A* and *B* communities enjoy clear passageways indicating the risk low and medium, respectively. As the size of the houses shrink with the *C* and *D* communities the passageways shrink with the additional household items stored in passageways, which would prove fatal in emergency evacuation resulting in increased risk.

46.3.1.6 Open Spaces Around Buildings

The question was formulated with options of widths for side margins as per the prevalent building regulations. The group *A* and *B* participants specify the availability of side margins and other open spaces like gardens and parking lots, indicating low risk, similarly group *C* participants agree on having availability of side margins, though less than requirement of building regulations. Group *D* participants deny the availability of side margins and accessibility to other open spaces in vicinity, indicating high risk to this indicator. The overall impact on resilience is positive.

The open spaces around the buildings are in form of the side margins which is a mandatory part of building regulations. The buildings occupied by group *A* and *B* communities have side margins and other open spaces conforming to the building regulations. The buildings occupied by group *C* communities compromise on the side margins, densely located which denies them 'safe' open spaces in emergency scenarios. The group *D* communities are densely populated with the access road as the only open space. The other spaces like gardens and play areas are privately owned spaces by housing colonies and public gardens have tickets denying access to open spaces resulting in high risk to group *D*.

46.3.1.7 Basements of the Buildings

The question was option-based formulated to understand the availability of basements and the facilities it sufficed. Few participants of group *A* and *B* remarked on inconvenience caused and high maintenance of the basement spaces due to water logging and underground water seepage issues in the event of rainfall indicating medium risk, while group *C* and *D* participants have marked absence of basements indicating low risk to this indicator. The overall impact on resilience is positive.

Basements of the buildings are used as parking areas conventionally in the city, as open space is scarce. Basement houses other service amenities like water storage tanks, electrical substations and sewage treatment plants. The parking requirement is huge with the group *A* and *B* communities hence basement is prime requirement in apartment buildings. Buildings in proximity to rivers and river tributaries and in dense built pockets of the study area have water logging issues in basements. Basements prove fatal in flood situations, with logging of water and silt. The group *A* and *B* communities are at high risk. The risk further increases due to the facilities accommodated in the basements like sewage treatment plants, electrical substations etc. Basements are uncommon in the buildings of group *C* communities, while group *D* communities do not have formal buildings, hence at low risk to this indicator.

46.3.1.8 Roof Top Terraces

Availability of roof top terraces is good indicator of preparedness during floods as safe places for evacuation. The group *A*, *B* and *C* participants have expressed the availability and accessibility of roof top terraces indicating low risk while the group *D* participants expressed the unavailability of accessible roof top terraces indicating high risk. The overall impact of the indicator on resilience is positive.

The conventional building typology in the city accommodates flat roofs. Roof top terraces act as the safe places for evacuation especially in flood situations. Most of the buildings in the city have roof top terraces which are accessible for routine purposes or rare purposes like evacuation in emergency scenarios. The group *D* participants have roofs built in tin sheets or thin RCC slabs making it inaccessible. In the months of monsoon, water logging in their houses is evident and people need to be evacuated to safer spaces away from their locations. This results in high risk to group *D* communities.

46.3.2 Structural Components

46.3.2.1 Construction Material and Technology

The questions framed for the indicator were choice based with options on construction material and technology conventionally adopted in the city. The group *A* and *B* participants chose the option RCC framed structure remarking on good quality of construction indicating low risk. The group *C* participants chose the same conventional construction technology however few participants remarked on poor construction quality with leakage and seepages issues. The multiple floor structures with poor construction quality and dense arrangement of buildings puts the buildings and occupants at high risk. The group *D* participants chose brick masonry and tin roofs and tin structures as construction material of their houses, single or double floor structures, indicating high risk in emergency scenarios. The overall impact on resilience is negative to this indicator.

The conventional material for construction is RCC frame structure and plastered brick masonry as infill walls. The construction material is typically same for the groups *A*, *B* and *C* however they differ in construction quality, technology and specifications. The favored construction materials in group *D* is tin sheets for wall and roof or unplaster brick masonry and tin roofs. The construction quality is poor posing high risk in emergency scenarios.

46.3.2.2 Earthquake Resistant Designs

Earthquake resistant designs are mandatory part of building regulations of the city. The group *A* and *B* participants remark on the conformance of building regulation for their apartment buildings indicating low risk, while many of the group *C* participants remark on non-conformance to building regulations indicating high risk. Group *D* participants remark on being unaware of the building regulations and earthquake resistant designs indicating very high risk to this indicator.

The groups *A* and *B* participants though unaware of the earthquake resistant designs have buildings designed as per the building regulations which incorporates the earthquake resistant design, hence are at low risk. The group *C* participants were skeptical about the earthquake resistant designs. The participants of group *D* were completely unaware of the earthquake resistant designs. The buildings and structures occupied by both these groups are not formally designed by architects as per the building regulations hence the structural stability cannot be guaranteed in case of emergency scenarios.

46.3.3 Safety Features

46.3.3.1 Firefighting System

Firefighting systems are mandatory for buildings above 21 m height as per the building regulations. The group *A* participants residing in high rise apartment buildings remarked on possessing firefighting system, however most of them expressed their ignorance on operating and maintaining the system indicating medium risk, while group *B* participants expressed though their buildings possess firefighting system installed by the developer are unaware of the operation and maintenance of the system indicating high risk. The residential premises of the *C* and *D* participants do not have any type of firefighting system and are completely dependent on external firefighting services indicating very high risk to this indicator. The overall impact of the indicator is negative on resilience.

The awareness on safety features lack among all the groups. The group *A* and *B* communities possess the firefighting system as a part of mandatory requirements of building regulations. The group *C* and *D* communities do not possess any type of firefighting system in their premises inspite of being densely populated. The awareness on fire safety is low among the communities though they possess the experience of fighting fire in emergency scenarios. The risk to these communities increase due to the inaccessibility challenges faced by the fire engines in reaching the hazard sites. The time delays can prove fatal to the communities.

46.3.3.2 Electrical Safety System

To ensure electrical safety the electrical system should be as per the mandatory regulations. Most of the participants from *A* and *B* group remarked on being unaware of the electrical safety systems and skeptical about the use of such system given in their houses by their developers during construction phase, indicating medium risk to this indicator, while participants from *C* and *D* groups remarked on complete unawareness of such systems they expressed their unaffordability to access the sophisticated electrical systems in their houses indicating very high risk to this indicator. The overall risk scenario is high for all the communities.

The primary cause of fire is the electrical short circuits. Electrical safety is thus important in any building. In emergency scenarios to avoid fires as the causal effect the electrical safety systems are important. The awareness on the mandatory requirements of electrical safety is low among all the communities. The group *A* and *B* communities have affordability to install the safety systems however the group *C* and *D* communities do not possess both. The electrical systems used in the houses are still crude in nature as revealed in field visits. Especially in the buildings which are more than 15 years old. The retrofitting and replacing of electrical safety system does not form the priority of these communities as it incurs costs as expressed in a stakeholder interview.

46.3.3.3 Maintenance of Buildings

The question was framed with multiple choices for understanding the maintenance of the residential buildings. Maintenance of buildings includes the repairs, and retrofitting as per the condition of the building. The group *A* and *B* participants remarked on having the system in place to address the maintenance issues however a proactive effort is missing in the system. The risk is yet low in this group. The group *C* participants expressed their unaffordability to bear the maintenance cost for their apartment buildings, while group *D* participants mentioned about the individual attempts conducted by each household for repair works required as per their affordability. It was evident from the field visits maintenance is not the priority of the community due to its comparatively high cost indicating high risk. The overall impact on resilience is negative.

Buildings need maintenance over period of time. The factors like climate and temperature, wear and tear of buildings can develop cracks and leakages in buildings, which if not addressed in appropriate time would further damage the building proving fatal in emergency scenarios. Buildings older than 10 years require refurbishment, retrofitting to match the current requirements. Sporadic and regular maintenance both is cost consuming. The group *A* and *B* participants can afford to maintain buildings timely, hence have low risk, while the group *C* and *D* participants expressed their financially unaffordability to maintain the buildings, dilapidating the buildings faster and increasing the risk to buildings and occupants.

46.3.3.4 Accessibility of Critical Services

The accessibility of critical services like fire engines and ambulances require road widths more than 3.0 m leading to the apartment buildings. The group *A* and *B* participants remarked positively on accessibility of these critical services indicating low risk. The group *C* participants expressed the challenges of accessibility due to narrow road widths, and haphazard road layouts. Group *D* participants remarked on the inaccessibility of these critical services due to absence of roads. Both the groups *C* and *D* participants indicate very high risk to this indicator. The overall impact of the indicator is negative on resilience.

The easy accessibility of critical services like ambulances and fire engine to the buildings is important for quick response and could prove lifesaving. The residential apartment buildings of group *A* and *B* communities have access roads wide enough for the easy access of these critical services. However the residential premises of group *C* participants have issues of inaccessibility for these critical services due to high density of buildings, haphazard layouts and lesser widths of access road. The group *D* communities are densely populated with encroached walkways to access the houses. The central core areas of the group *D* settlements can be accessed by walkways or two wheelers resulting in high risk to communities in emergency scenarios.

46.4 Conclusion

The safety of the residents and occupiers depends on the safety measures inherently integrated in planning and design of the buildings. The study reveals the disaster risk is low when the buildings are integrated with the prevention and mitigation measures, in its architecture and design. Creating safe buildings and households requires sensitivity and awareness among the architects and the occupants. The study implies the role and importance of architects in contributing to resilient infrastructures. It is evident from the study, in the low income communities, wherein planning and design has minimal or no role of architects are more vulnerable to natural hazards. Architecture, consciously developed or unconsciously evolved, needs dedicated efforts to absorb the shocks of disasters by adopting and integrating prevention and mitigation measures according to its risk exposure. Architecture thus is a key to prevent and mitigate the risk of natural hazards.

46.5 Way Forward

Architecture is more than creating great looking buildings. Role of architects is paramount in planning and design of buildings for low income communities. Architects need to be sensitive and proactive in understanding the rare and the routine risks and designing responsive structures. Resilient communities can be formed through resilient architecture. In this study the authors have attempted to establish relation between architecture and resilience of structures to natural hazards. There are various other perspectives to view this relation while expanding the scope of the study further.

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