

## Understanding Patterns of Physical Transformation in Reconstructed Settlements: the Case of Post-Earthquake Housing in Marathwada, India

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### Abstract

This paper describes how planning and design of reconstructed settlements after disasters impacts the way people make changes to their living environment. It also elaborates on the design parameters that influence culturally appropriate and sustainable housing. The paper further attempts to understand the long-term impact of rapid changes in the post-disaster built environment and the adaptation strategies of communities for meeting their socio-culturally and climate specific needs. It also illustrates how new house designs and building technologies have influenced people's own building practices and their implications on disaster vulnerability, especially to earthquakes. All these issues are illustrated through the case of post-earthquake reconstruction in the Marathwada region, in India. Four relocated villages and one traditional village were studied. Patterns of transformation of both traditional and relocated settlements were analysed by mapping built and open spaces, vegetation, street furniture, infrastructure and sacred spaces at the settlement and neighbourhood levels. The social structure of the settlements was spatially recorded. At the housing level, changes in the layout, space usage, materials and construction technologies for additions were analysed to understand the patterns of transformations and their socio-cultural and environmental impacts on the inhabitants. The implications of different combinations of materials and technologies were analyzed with respect to structures' safety and durability. This data was recorded through drawings and photographs and consequently related to socio-economic variables. The paper concludes by highlighting essential considerations for the planning and design of post-disaster settlements and housing to enhance long-term sustainability and disaster risk reduction of communities.

**Keywords:** Transformations, Reconstruction, Adaption, Vulnerability, Sustainability.

### Introduction

Reconstruction following disasters often entails dramatic changes in settlements' location and morphology, housing designs, building materials and construction processes. These considerations raise a number of questions that thus far have gained only limited attention and can only be answered through interdisciplinary longitudinal research undertaken several years after external agencies' contribution to reconstruction is completed. The paper aims to address these issues in the context of the Marathwada region located in Maharashtra State of India, whose traditional built environment has undergone dramatic changes in relation to massive resettlement and reconstruction projects following the devastating earthquake in 1993.

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This paper is based on one of the objectives of the research project “Understanding habitats, housing and social changes in post disaster traditional and relocated rural settlements in India”, undertaken by the World Habitat Research Centre with the support of the Swiss National Science Foundation. The research project focused on the patterns of evolution and transformations of old and new settlements. It aimed to analyse the type of modifications and additions people undertake in their settlements and houses and to identify the opportunities and challenges that different settlement plans, house designs, and building technologies pose with regard to transformation processes. At the household level, objectives and strategies of transformations were analysed in relation to social variables, such as caste, occupation, and household composition; at the neighbourhood and village level, transformations were analysed with reference to the socio-cultural specific needs they aim to fulfill, such as caste-based neighbourhoods and open community spaces for festivals and gatherings.

To understand the transformation process and the adaptability of the inhabitants in the relocated villages, four relocated villages and one traditional village, in the Marathwada region of India were studied. These villages were chosen based on their layout planning, reconstruction building technologies and socio-economic structure. Patterns of transformation of both traditional and relocated villages which happened over a span of 18 years (from 1993 to 2011) were analysed by mapping built and open spaces, vegetation, street furniture, infrastructure and sacred spaces at settlement and neighbourhood levels. Also, the social structure of the settlements was spatially recorded. At the housing level, changes in the layout, space usage, materials and construction technologies for additions were analyzed to understand the patterns of transformations and adaptation along with the socio-cultural and environmental impacts on the inhabitants. The implications of different combinations of materials and technologies on the vulnerability of structures were subsequently analysed.

## **Post-Earthquake Reconstruction Process**

Latur and Osmanabad are two districts located in the Marathwada region, about 500 km east of Mumbai. Before the area was hit by an earthquake that killed over 8000 people in September 1993, around 87% of inhabitants lived in traditional stone masonry houses (Parasuraman, 1995). The earthquake affected about 190,000 houses distributed in over 2,500 villages; and 52 villages counting a total of 28,000 houses were fully destroyed (Government of Maharashtra, 1993). Only a few days later, the Government of Maharashtra announced its reconstruction program called and 52 villages counting a total of 28,000 houses. Programme”ogrammelater, the Government of Maharashtra announced its reconstruction program called and 52 village donor agencies, and NGOs. The affected villages were divided into three damage categories: relocation and full reconstruction was foreseen for the 52 most heavily damaged ‘category A’ villages; reconstruction in situ through financial assistance for ‘category B’ villages; repair and seismic retrofitting of about 190,000 damaged houses for ‘category C’ villages. Entitlements to housing assistance were divided into three categories of people: landless and marginal landholders would be given houses of 250 square feet; households owning between one and seven hectares of land would get houses of 400 square feet, and households owning more than 7 hectares of land would get houses of 750 square feet. New standards were set for housing construction that advocated the use of earthquake-resistant technology. The government managed to arrange the participation of a large number of non-governmental agencies in the program, including commercial firms, international donor agencies, religious groups, and political parties, among others. These agencies came up with a variety of building technologies to demonstrate seismic resistance. The entire reconstruction activity was primarily contractor-driven where contractors and labour were hired by donor agencies coming from outside the region to undertake reconstruction.

Since the commencement of MEERP, the World Bank required the complete participation of the affected population in the rehabilitation process. This feature, the first of its kind in any government project so far, projected MEERP as a classic model to resettle and rehabilitate large groups through the provision of housing, infrastructure and other socio-economic facilities like open community spaces for festivals and marriages, and temples and mosques for the local population. To act as an interface between the government and local communities, Community Participation Consultants (CPCs) were hired by leading social organisations (Jigyasu and Salazar, 2010).

The planning of relocated settlements was taken up by various donor and government agencies and consequently many different layouts and designs were explored of which the most common was a grid iron pattern (fig. 1 left). While traditional settlements were characterised by narrow streets, a hierarchy of public and private open spaces used for religious as well as other activities, clusters of housing with distinct typologies were characterised by traditional occupation patterns. However, in most of the cases, what was designed for them was a complete 'city-like' plan with wide streets forming a grid pattern, and row housing. Only in some rare instances was cluster-type planning done (fig. 1 right), supposedly inspired by the traditional village layout (fig. 2) (Jigyasu, 2001).

The new designs didn't include spaces for several traditional activities, especially those of service sector people like artisans. Moreover, the new villages' area was much larger (sometimes up to ten times) than the old ones'. This meant expensive infrastructure, which was again 'provided' by the Government (Jigyasu, 2002).



Figure 1: Left: relocated village of Sirsal's grid pattern layout; plan of 1996. Right: relocated village of Malkondji's cluster type layout; plan of 1996. Source: MEERP, 1996.



Figure 2: Traditional village of Almala's organic layout. Source: Authors, 2011.

### Traditional Versus Reconstructed Houses

The common typology of a vernacular house in this region is the "Wada" made of high dry masonry stone walls and organised around an inner central courtyard surrounded by rooms on each side (fig. 3). The typology also presents a front yard.

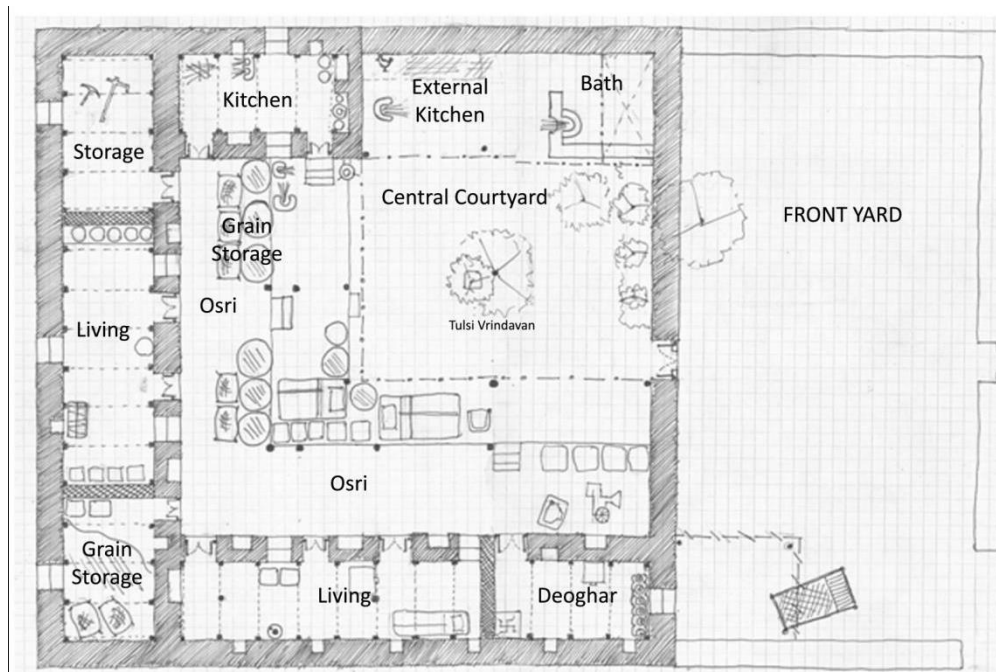


Figure 3: Traditional Wada House at Lamjhana Old village. Handsketch by N.Upadhyay, 2011.

Various designs of three sizes were proposed for the reconstructed dwelling units. Sizes were decided based on the size of the land owned by the affected family. The basic design of the house was, in some cases, very comparable to the traditional Wada, while certain designs bore no resemblance to the vernacular architecture. In Gubbal, two such extreme cases could be observed, where the Government of Maharashtra constructed houses with close resemblance to the vernacular architecture (fig. 4 left) while the donor agency AADRA created earthquake resistant ferrocement domes (fig. 4 right), a completely alien technology and shape for the region of Marathwada.

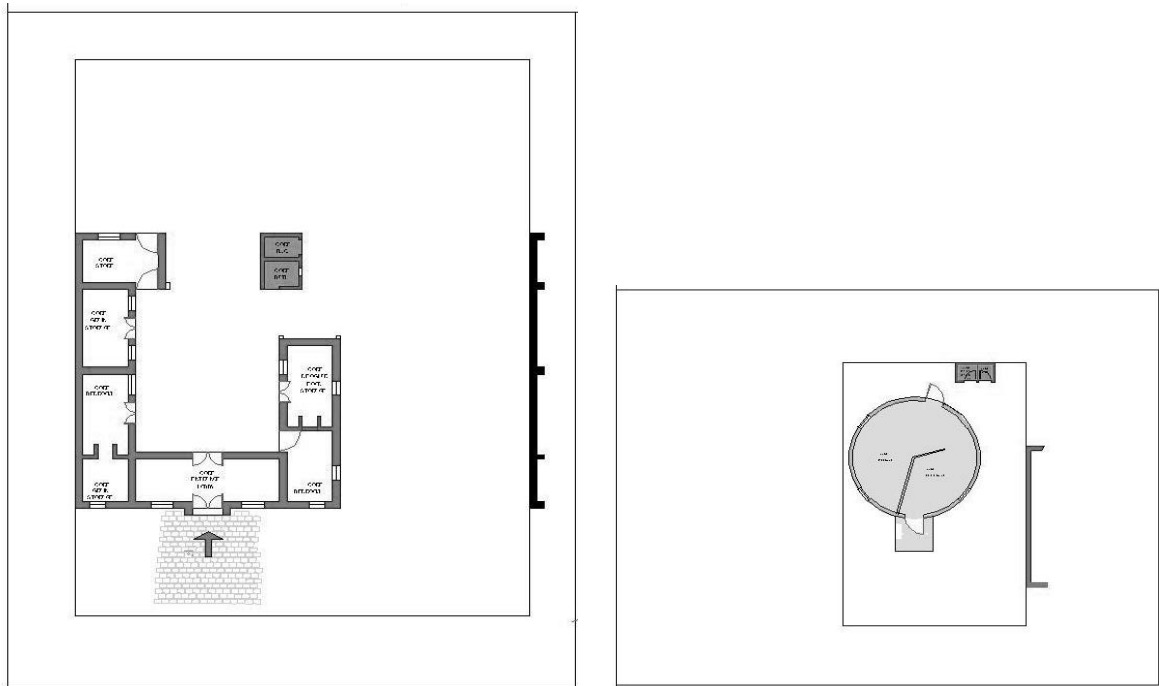


Figure 4: Left: Category C house in Gubbal with the Introvert plan of the house based on vernacular architecture, built by the Government of Maharashtra. Source: Authors, 2011. Right: Category B house in Gubbal, with circular plan and ferrocement partitions inside to divide the living spaces, built by AADRA. Source: Authors, 2011.

## Transformations in Relocated Settlements

### Status of Public Spaces and Infrastructure

Given the abundant space available, the reconstructed villages have transformed over the span of 18 years (1993-2011) according to the growing population and villagers. The donor agency AADRA created earthquake resistant and green areas in the layout of reconstructed villages (such as Lamjhana) remain mostly unused and are in some instances even used by villagers for open defecation. These spaces were created with an urban vision because rural activities did not require them. On the contrary, people have added social meaning to some open spaces that originally had no specific destination. For example, in Malkondji the well-shaded road next to the main chowk (village center) becomes the place for the elderly to gather and relax under the shades of Gulmohur trees. In Gubbal, the village has become culturally and socially richer due to the addition of a big Mosque and two temples in open areas. The scarce development of some community spaces is mostly because of the weak interaction between social groups, while certain usages that were not

foreseen at the time of design evolved later as the villagers tried to adapt given spaces to their socio-cultural needs.

In some relocated villages, public buildings accommodating new spaces like a gymnasium, library and centres, were constructed according to the original layouts. However, except for the women centre, all the rest of the buildings are now either locked up or not being used as the design intended. As a result, these are deteriorating due to lack of maintenance. Nevertheless, buildings like Mahila Kendra (Women's Centre) actually contributed towards strengthening the cooperation among women by providing a common space where they could meet and discuss. This space is also used as an adult education centre with social workers imparting basic education and informing the villagers about the recent government schemes regarding the subsidies and public fundings for improved agriculture and irrigation methods. Over a period of ten years from the time of reconstruction, new buildings have been constructed by the villagers to cater to their special needs; it is the case of the grain storage in Malkondji. Other public buildings addressing local needs and therefore successfully used in the villages are the Panchayat building, Aanganwadis and primary schools.

### **Reinforcing the Socio-religious Context in New Settlements**

In many relocated villages, temples and mosques have been added through joint efforts of the community. For instance, the Sirsal Temple was constructed jointly by inhabitants and the village panchayat (the local governing body) with an elaborate spire (fig. 5). It is dedicated to Lord Shiva and used by the Hindu community for religious and cultural gatherings.



Figure 5: Temple in Sirsal. Source: Pittet, 2011.

In Malkondji, the villagers brought all the major deities from the old village and made new temples for them. And also the original Deep mal (lamp-tower) was brought from the old to the new village. Villagers employed expert masons to first dismantle the Deep mal at its original site and later get it perfectly reconstructed in the main public square of the new village, opposite the main temple. This is a very significant attempt by the villagers to revive

the old village ambience and culture in the new village. However, many villagers still visit the shrines in the old village, especially during special festival days.

In the relocated village of Lamjhana, people visit the shrine of a saint and organise an annual fair (Urs) around it. Also, after marriage ceremonies, the newlywed couple pays a customary visit to the temple in the old village to get the blessing from the local deity. Similarly, in Malkondji, a seven day festival is celebrated and organised around the temple of the local deity, situated in the old village.

### Social Structure of the Village

The social structure in the region is based on the caste system that has traditionally determined the location of various social groups in the villages. However, in most relocated villages, the distribution of houses was defined according to the size of land holdings; therefore the socio-spatial structure of the village may or may not correspond exactly with that of the traditional village. While in some villages like Malkondji, mixed castes are still found to be living together, in others like Sirsal, the social-spatial structure of the relocated village is found to be very similar to that of the old village (fig. 6 left, right).

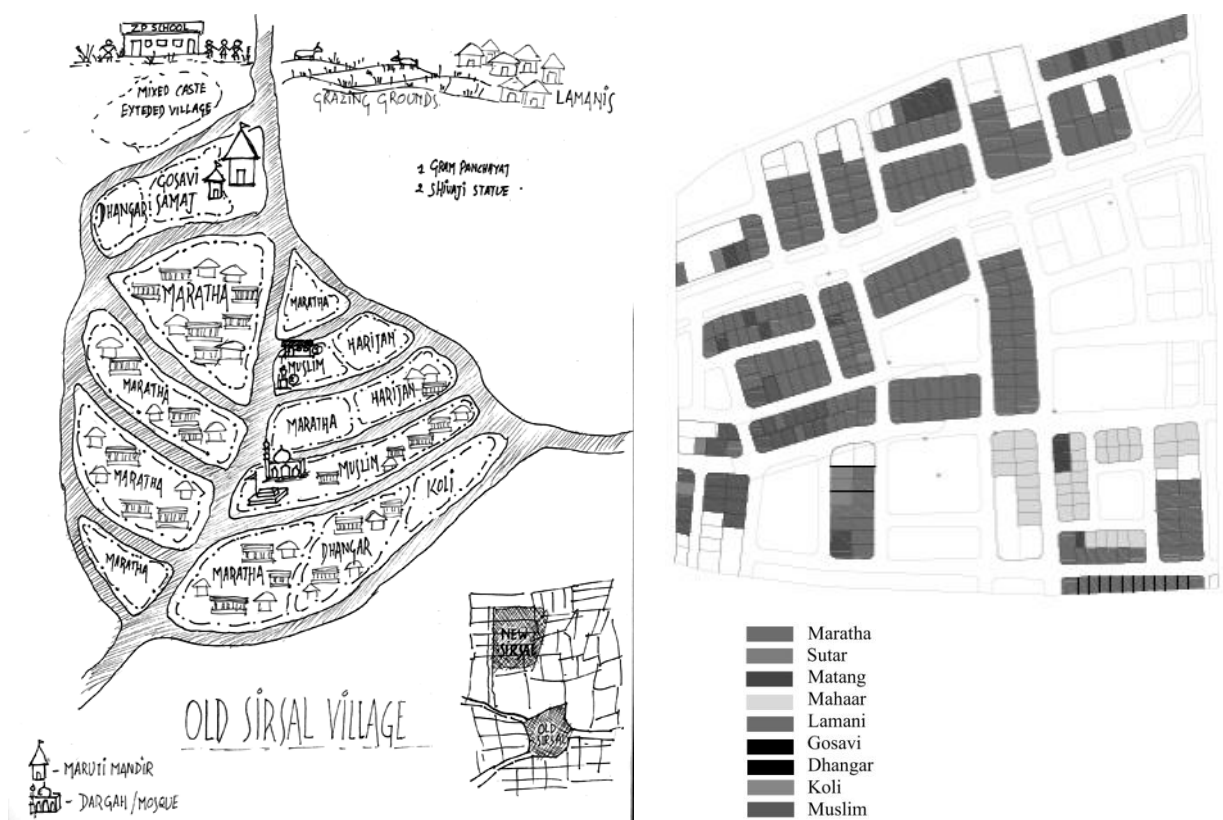


Figure 6: Left: Caste mapping of old Sirsal settlement. Below on the right, a map of the old and new village with the road network. Elaborated through participatory mapping (hand drawing by N. Upadhyay, 2011); Right: Caste mapping of new Sirsal village done in 2011, showing the similarity between the two stages in terms of socio-religious planning.

Source: Authors, 2011.

## Internal Densification

The relocated settlements have not changed in their overall size, but have densified inwards (figs. 7, 8). Therefore the built area within the village increased as the families expanded. This is because of the availability of larger plots in relocated villages that allowed people to make extensions to their core houses.

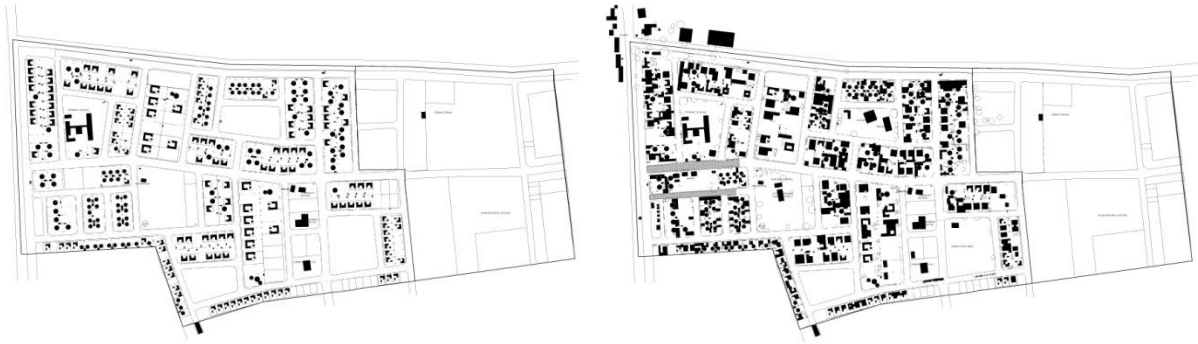


Figure 7: Gubbal village density. Left: at the time of reconstruction; Right: in 2011. Source: Authors, 2011.



Figure 8: Malkondji village density. Left: at the time of reconstruction; Right: in 2011. Source: Authors, 2011.

## Transformation in the Circulation Pattern

Most of the relocated villages are still kutchra (official terminology for mud houses). In villages with the grid iron layout, the space in between the rear of two houses is not enough to facilitate the evolution of laneways or shortcuts, which tend to evolve in an organic manner in traditional settlements. Exception to such layout schemes include certain villages like Malkondji and Banegaon, which have cluster layouts. In these villages, the organic



streets and the interconnecting laneways that have evolved within the formal layout provide flexibility in movement throughout the village and also facilitate social interactions. Also, such layouts have given more room to the evolution of informal routes and lanes on public land, whereas in villages with grid pattern layouts, such informal paths tend to evolve at the cost of private plot spaces, encroaching upon them.

## **Transformations at the Neighbourhood Level**

At the neighbourhood level, the usage of semi-public spaces or courtyards varies across the different relocated villages depending on their original layout and design and the additions done afterwards. Accordingly, these spaces are put to various uses such as keeping livestock, parking bullock carts, threshing and storing the harvest, storing firewood and fodder for cattle and dried cow dung cakes during the dry season. These spaces are also occasionally used for social ceremonies like marriages.

Contrary to the traditional villages, the neighbourhood areas in the new villages are much larger in area. This creates open spaces, compared to the introverted spaces in the traditional village with intimate streets and juxtaposed houses. Also in traditional villages, the cattle are tied in the cowsheds built in the farmland, while in relocated villages, the cattle were tied within or outside the plot boundary of the houses. This has resulted in a marked shift in the living pattern in these villages.

Well-defined plot boundary walls play an important role in fostering better relations among the villagers and avoiding encroachment-related disputes. In Malkondji, the village design has not only respected the existing caste structure, but also successfully created small social spaces which facilitate social interaction within and among various social groups in the village. The grid pattern layout adopted in other relocated villages fails to create any resemblance to the neighbourhood planning in a traditional village of the region.

Moreover, the traditional narrow streets (about 3.5 meters width), as in the Almala village, have sitting platforms on both sides that create a more intimate atmosphere compared to the broad streets of relocated villages (approximately 4 meters with a 1.5 meter wide footpath on either side) such as Malkondji. Broader streets in relocated village offer more safety against earthquakes, but a less intimate environment.

## **Types of Changes/Extensions in Reconstructed Houses**

Big change is seen in the use of materials and construction systems in the extensions done by the villagers. These were documented by mapping the house and discussing the chronological development of the house with the owner.

In all of the case studies, the space immediately added to the original structure is a kitchen. In fact, the core house design clearly does not consider the rural ways of cooking food, as they lack a chimney for the smoke produced during cooking food on conventional Chulha (firewood stove). Therefore, the first post-relocation extension was the construction of a kitchen (fig. 9 left), followed by the construction of a storage space, a Dhelaj (elaborate threshold of a traditional wada house) wall (fig. 9 right) and a toilet.

The transformation process at the house level is very noticeable and its reasons are quite clear; these are shown in table 1.

Table 1: Transformations at the house level.

Transformation (in order of priority)	Reason
Kitchen	The core houses design did not consider the fact that a chulha (stove that uses firewood) is predominantly used for cooking in rural areas. Thus a chulha, when used inside the room would blacken all the walls with soot and risk leading to suffocation.
Storage	Covered storage for harvest, grains, firewood and fodder was one of the immediate needs addressed by building another extension. In the absence of a storage area, the villagers are bound to keeping their belongings in big chests that occupy most of the space in the core house.
Living	Shaded areas covered by tin sheets were created to sleep underneath due to the psychological fear of a heavy roof caving in, in case of another earthquake. In most cases, the living area and storage were two different uses in the same extension.
Dhelaj / Dhelaj Exterior walls	The walls we constructed either by salvaging the dressed stone from the old village or by making walls out of Gattu (Cement Concrete Blocks). The chaukhat (door frame) was brought from the old village. The construction of Dhelaj shows the strong aspiration of villagers to recreate the traditional Wada typology in the reconstructed houses.
Toilet	Though the toilets were already provided in the core houses, the expansion of families and splitting of households in a plot led to the need of more toilets per plot. When the toilet demand went high, people opted for open defecation in the farms. It is only recently, when the Panchayats of the respective villages made it compulsory for all houses to have toilets, that people constructed toilets in their plots.



Figure 9: Left: Extension to accommodate the kitchen; Right: Extension for Dhelaj. Source: Authors, 2011.

The types of extension done to the houses are also linked to the inhabitants' socio-economic background. Castes like Maratha and Brahmin were observed to be financially better off than castes like Lamani and Dhangar, and thus the extensions done in the houses are more elaborate in the former cases than in the latter ones. Moreover, certain castes observe more religious rituals, which also affect the evolution of the houses as they try to make a dedicated place of worship in the house.

### Transformations Guided by the Location of Core House in the Plot

The location of the core house in the open plot is also a very significant factor that determined the pattern of later extensions. The plots where houses were located at the extreme end proved to be the most convenient for extensions, while those having the built blocks placed in the middle of the plots were not suitable for extensions. In such cases, the rear of the plot could not be used due to inaccessibility, and so the extensions were built in the front, often encroaching upon the public land beyond the plot boundary (fig. 10).



Figure 10: House in Sirsal. Core block at the center of the plot. Source: Authors, 2011.

### Transformations Guided by the House Design

In the case of Gubbal, the circular plan and the curved ferrocement walls made it impossible to make strong extensions that were integrated with the core units. However, it allowed the villagers to make the extensions around the dome completely surrounding it and creating an intimate open space in between the dome and these extensions (figs. 11, 12). In many such cases, the house entrance with dhelaj (platform for sitting on both sides) often looks like a typical Wada style house.

One small, yet very significant flaw in the design of the new houses in all of the relocated villages was the absence of built-in storage spaces in the walls of the rooms. Therefore, most of the core block rooms were used to keep the storage furniture like steel boxes and cupboards. The traditional houses of the region had very thick stone walls that not only gave room to create built-in storage spaces in walls, but also improved the thermal retention of the house.



Figure 11: Extensions around the dome house in Gubbal, hiding the dome from the view.  
Source: Upadhyay, 2011.

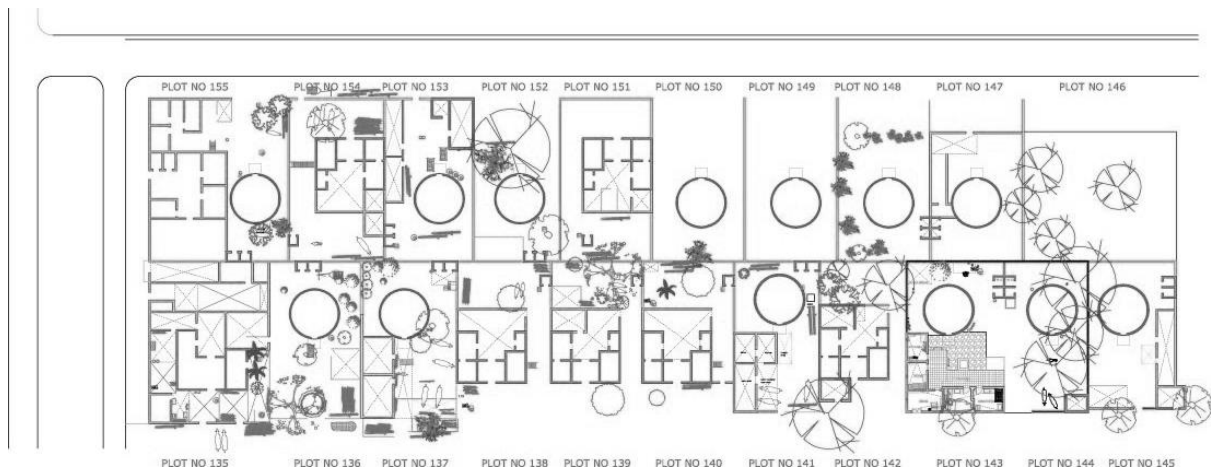


Figure 12: Extensions around the core houses (domes) in the relocated village of Gubbal.  
Source: Authors, 2011.

### Changes in Construction Materials

The core houses in all 26 case studies in the three relocated villages are intact, without any alteration. However, in most cases people have used the core house walls to support the extensions. They have used tin sheets on the walls and supported them by timber posts wherever required. Materials used to build the extensions include Reinforced Cement Concrete (RCC), Ferrocement, cement concrete blocks and bricks. Stones are used only at the foundation level.

The use of a certain material of construction also depends upon the socio economic status of the house owner. For example, in Malkondji it was observed that Maratha, Brahmin, Lingayat and Muslims used stone or brick for the extensions (fig.13 left), whereas other castes like Maang and Mahar were seen to be using wattle and daub to create partition walls in extensions undertaken in their houses (fig. 13 right).

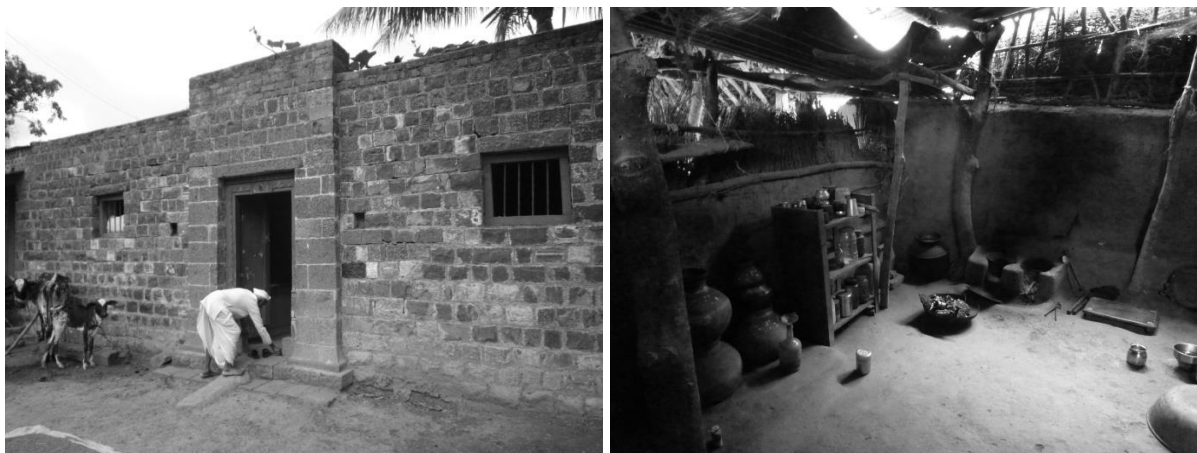


Figure 13: Left: Lingayat house with elaborate stone and brick extension; Right: Mahar house with wattle and daub extension. Source: Authors, 2011.

As per the data obtained from the 26 case studies done in three relocated villages, the materials used for the houses extensions shows an increasing trend towards galvanized iron (GI) sheets for roofing and walls. In the extensions done in all case studies in the relocated villages, 79.7 percent of roof materials and 26 percent of walling materials was GI sheets. But, in the traditional village of Almala, the most drastic change concerned the roofing material. Before the earthquake, Malwad (traditional dry stone masonry with wooden beams and posts and mud roof) roof was predominant, while GI sheet roofing became predominant in 2011. Table 2 shows these changes in the use of construction materials.

Table 2: Changes in the type of construction materials used in the traditional village of Almala. (Courtesy of: Pittet and Upadhyay, 2011).

Construction Material change observed in Almala								
Case study n°	Roofing materials before EQ				Roofing materials In 2011			
	Tin sheet	Malwad	RCC	Thatch	Tin sheet	Malwad	RCC	Thatch
Case Study 01	16	84			86	14		
Case Study 02		100			62	38		
Case Study 03				100	100			
Case Study 04		100			100			
Case Study 05		100			86		14	
Case Study 06		100				100		
Case Study 07		100			53		47	
Case Study 08				100	100			
<b>TOTAL</b>	<b>16</b>	<b>584</b>		<b>200</b>	<b>587</b>	<b>152</b>	<b>61</b>	<b>0</b>
<b>%</b>	<b>2</b>	<b>73</b>	<b>0</b>	<b>25</b>	<b>73.4</b>	<b>19</b>	<b>7.6</b>	<b>0</b>

Results show a general trend towards the use of GI sheets for construction in the region, irrespective of whether it is a relocated village or a traditional village. One explanation for this trend could be the affordability of the GI sheets and the ease of the construction process. Another explanation is that people’s fear of earthquakes makes them opt for lighter materials for roofing. In the 1993 earthquake, many people died due to caving in of the heavy roof, thus people are now ready to compromise on the quality of life to increase life security. In fact, in summers, temperature within these GI sheet extension goes much higher than the comfort limit, due to the thermal properties of the material.

### Impact of Transformations on Physical Vulnerability

A radical shift in material and construction techniques has also affected the vulnerability of the houses and their residents. To illustrate, 26 case studies were chosen as samples from the three relocated villages to identify the houses’ vulnerability patterns. Figure 14 shows what type of defects and their frequency were found there.

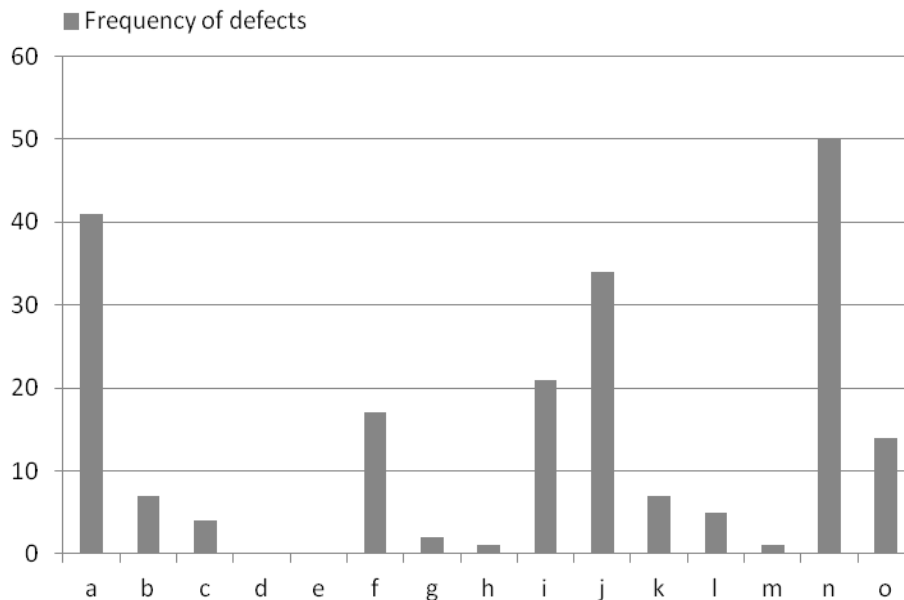


Figure 14: Frequency of defects in studied houses in the relocated villages.

Legend

a. Poor corner joints between walls	i. Improper stone/brick masonry
b. Inadequate/Improper reinforcement	j. Hybrid use of materials for walls
c. Improper thickness of slab	k. Improper location and size of opening
d. Inadequate cross-section of column	l. Inadequate foundation
e. Inadequate joints between RCC columns and beams	m. Inadequate joints between foundation and walls
f. Inadequate joints between walls and roof	n. Discontinuous/no lintel band
g. Irregular spatial configuration	o. Others: stone on the tin sheet.
h. Heavy roof with thick mud layer	

The absence of lintel band or its discontinuity, hybrid use of materials for walls and improper brick masonry were found as the most recurring defects in the houses, which contribute to their seismic vulnerability (figs. 15 left and right).



Figure 15: Left: Muslim farmers' house in Gubbal made of independent brick structure of high walls without horizontal tie band; Right: Dhangar house in Gubbal made of hybrid material walls. Source: Authors, 2011.

During reconstruction, various construction techniques were introduced that had to be rapidly learnt by the local masons. However, without proper supervision, basic quality standards for such type of constructions could not be established.

The Dome Houses in Gubbal are very stable structures, but not resistant enough to support any extension. Thus, the extensions built around them are independent brick masonry structures that lack continuous bands to stabilise their structure (fig.16 left). Also, their walls are constructed in poor masonry using hybrid materials (fig. 16 right), thereby increasing their vulnerability to earthquakes.

People structure (fig.16 left). Also, their walls are constructed a strong but false perception that if they use brick masonry and tin roofs, the combination gives a sturdy yet light construction that will not collapse in the event of an earthquake. However, tin roofs become highly vulnerable to the strong winds in the area, and to reduce this vulnerability, roofs are tied down by heavy stones that prevent them from flying away. But in some cases, villagers just keep heavy objects and stones on weak tin sheet roofs, which make the house even more vulnerable.

Also, due to the general misperception among residents that only roof collapse can cause the damage, not much attention is paid to walls, which are built with poor masonry. A vulnerability analysis of 8 case studies of houses in the traditional village of Almala shows that the most common defect was poor corner joints in walls and poor masonry with additions done in hybrid construction materials (fig. 16 right), thereby making the houses highly vulnerable to earthquakes. In several instances, the core houses also show water leakage problems in the roofs.

For making new additions, people prefer financial savings over seismic concerns and security. A mason interviewed during the field survey said that on an average, an extra 10,000 Rupees are required to cast continuous lintel bands in the construction of a room of 12 square meters, which people generally skip in order to save money.

Different social groups implement different types of house extensions, which also differently affect their vulnerability. The social survey and vulnerability analysis indicates that vulnerability to earthquakes of middle class and wealthy farmers whose house extensions are made of materials such as brick/stone without lintel bands are much more vulnerable than those of the poor farmers/agricultural labourers who have constructed their house extensions with wattle and daub or with wooden posts and tin sheets.



Figure 16: Left: High masonry walls lacking lintel bands in a Muslim farmer family house in Gubbal; Right: Wall made of hybrid materials in a Maratha farmer family, in Malkondji. Source: Authors, 2011.

In C category villages, the houses were only repaired and retrofitted by government agencies and NGOs, as they did not suffer much damage from the earthquake. The traditional Malwad houses were strengthened by tying the whole wooden frame of beams and posts with L angle steel brackets (fig. 17 left). Despite training programs on retrofitting techniques for C Category houses conducted by some NGOs, most residents had not understood retrofitting basic principles and techniques. In one house, the owners had even removed these brackets in order to increase the height of the roof by making inappropriate additions to walls, and replaced the roofs with tin sheets (fig. 17 right).



Figure 17: Left: Retrofitting technique used in Kharosa (C category village): wooden beams and posts tied through steel brackets; Right: Brackets introduced after the earthquake for retrofitting a traditional house have been removed by the owners to increase the height of the roof and replace Malwad with tin sheets. Source: Authors, 2011.

## Conclusions

This research led to some important conclusions regarding sustainable reconstruction in a post-disaster scenario.

- People can adapt any space according to their lifestyle as long as they are given certain basic positive conditions like a favourable typology of house design and favourable location of built block within the plot.
- Public spaces in post-disaster reconstructed villages in rural areas should be designed considering the villagers' socio-cultural needs and lifestyle. For this, the villagers should be constantly engaged in the process of designing a settlement layout.



- Culture is a paramount issue and community-driven initiatives to create socio-cultural spaces within the village should be well supported by agencies responsible for post-disaster reconstruction.
- Attention should be focused on the communities' socio-spatial structure in a reconstruction programme. In fact, if post-disaster reconstruction provides an opportunity to mix various social groups in an equitable manner (compared to the hierarchical structure of traditional villages), it can also lead to more social conflicts if not undertaken diligently. A balanced consideration of all factors can not only lead to a harmonious environment in the resettled settlement, but also pave the way to a very positive development of the settlement through social cohesion.
- Attempts should be made to understand traditional architecture and the daily life of disaster-affected people for designing houses for reconstruction that are easily adaptable by the inhabitants.
- Introduction of new construction technologies should be carefully evaluated in terms of resistance to different hazards, socio-cultural compatibility, and affordability. Masons should be trained to follow basic construction standards while using local materials. A lack of knowledge among masons often leads to poorly constructed extensions of the given houses.
- Small details can make a very large difference in people's lives in a relocated village. For instance, in the Marathwada region:
  1. Making boundary walls around the plot can not only clearly define the plot, but also help in avoiding encroachments and related arguments among the neighbours;
  2. Making built-in storage spaces within the given house helps people to better organise the house and use spaces for active functions rather than storing goods.
  3. Special consideration requires the design of the cooking area in the house. In the case of Latur, the kitchen was not designed to allow ventilation in order to use firewood, thus the owners immediately had to make an extension for the kitchen.
- Awareness programs should be regularly organised to make new generations aware of the losses people incurred in previous disasters, and inform them about the safety measures that need to be undertaken for making new constructions that are disaster resilient.

Most importantly, the aforementioned points would necessitate the right kind of community engagement during the reconstruction process to ensure long-term sustainability.

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