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Advanced documentation technologies for people-centred preparedness and *re-construction* in Bela, India

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Abstract

Purpose – Despite the recurrence of earthquakes, responses are usually triggered afterwards, lacking mitigation strategies to diminish risks. Damaged dwellings cannot be immediately reinforced to continue inhabitation, generating disruption. Repairs are usually costly, as large numbers of affected constructions make damage assessment difficult, and post-earthquake reconstruction programmes often lack a heritage-specific approach. This research seeks to address these issues through a methodology based on high-end documentation technologies applied to built heritage and local community engagement.

Design/methodology/approach – The methodology proposed combines different recording tools to capture social and built environment data, such as interviews, mapping, drone capture, photography and 3D laser scanning, in the pilot case study of Bela, a historical settlement in the seismic region of Kutch in Gujarat, India, affected by the 2001 Bhuj earthquake. This paper particularly discusses aspects of community engagement around data capture and representation processes.

Findings – The introduction of advanced documentation technologies can help speed up the process of damage assessment, analyse social aspects that are key to a respectful *re-construction*, and enhance community engagement through visual representations, which are relevant to social acceptance and understanding towards a meaningful introduction and sustained use in earthquake risk management.

Research limitations/implications – The methodology proposed can inform similar cases in seismic areas and enhance engagement, helping to develop a sense of awareness in the community regarding the need for preparedness in the face of earthquakes. However, there are technical challenges in using advanced recording technologies in terms of equipment accessibility, skills, knowledge and future uses of the data. Social and cultural aspects, such as caste and gender divisions, also implied disparity in accessing the data and relating it to the research team, bringing forward the need to tailor public engagement to achieve inclusivity.

Practical implications – This study has practical implications. The most relevant one is how the process of carrying out the research served as a way to raise awareness for future seismic events. In this regard, local

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academic institutions and non-governmental organisations (NGOs) are critical mediators in reaching the community in greater depth, from which to bridge to external and/or governmental agencies based on existing links and trust.
Social implications – This study also shows social implications. As a case study-based research, the link developed with the local community will help coordinate actions in case an earthquake occurs and increase cohesion within the community towards a joint aim, in this case, to reduce the risk of disasters due to seismic events.
Originality/value – This paper accounts for a novel approach to documenting buildings in heritage settlements prone to earthquakes that uses the digital record as (1) a basis to assess and intervene in the built environment and better understand how it supports the local community's ways of living and maintaining buildings; and (2) a platform for local engagement and agency in planning and *re-construction* as a post-disaster mitigation measure.

Keywords Community engagement, Bela, Earthquake risk management, Re-construction, Digital documentation, Built heritage

Paper type Research paper

Introduction

Disasters can deteriorate and damage vernacular buildings in heritage settlements. When located in seismic areas, this built heritage is at greater risk due to earthquakes posing a recurrent threat. This non-monumental heritage is constructed mainly by inhabitants as an affordable response to local climatic and environmental conditions; examples of sustainable building techniques using local materials and labour, as well as passive design strategies (Plate 1). The authors understand these dwellings as the built expression of their inhabitants' cultural heritage. After earthquakes, some of these buildings are usually not completely destroyed and continue to be in use despite their damage, which poses a risk. In this context, repair and retrofitting are urgent actions that can help to tackle that risk and sustain the continuation of inhabitation, ultimately contributing to maintaining the social capital of communities living in their same built environments and positively contributing to their post-earthquake recovery. However, existing post-earthquake repair and reinforcement actions are hard to implement at a large scale due to the difficulty of working with the as-built condition of buildings and their remains. Pereira-Roders and van den Brand (2006) suggest

Source(s): 3D for Heritage India Research Project. Author: B. Devilat

Plate 1. A dwelling damaged by the 2001 Bhuj earthquake in Bela, India. November 2021

that building rehabilitation lacks technical development compared to building anew. There is a knowledge gap in addressing damage mitigation and repair in buildings in seismic areas as a large-scale strategy instead of reconstructing from scratch. In this context, a critical challenge is documenting what is left after an earthquake, which can be expensive and time-consuming, and working with the local community to integrate them into the decision-making process.

Focusing on the built environment, advanced recording technologies, such as 3D laser scanning (LiDAR), in combination with photography and drone surveying, can be beneficial for studying and conserving historical structures by capturing a large amount of measurable data in a short period (Devilat, 2021), offering a range of possibilities for heritage conservation. These technologies have been used for surveying and documenting buildings affected by or at risk due to earthquakes (Olsen *et al.*, 2013; Rastiveis *et al.*, 2015; Sharma *et al.*, 2017; Mohammadi and Wood, 2018; Dominici *et al.*, 2017; Devilat *et al.*, 2021; ICCROM *et al.*, 2022; NTU *et al.*, 2022), and more broadly for documenting the built heritage in general.

Nonetheless, neither the potential of addressing the scale of a whole settlement with the comprehensiveness and accuracy of the survey of a single building has been fully explored, nor has its possibilities to enhance community participation. Similarly, an architectural perspective using high-end technology to document heritage in post-earthquake contexts where resources are scarce seeks to bridge a gap between immediate emergency measures (generally from a humanitarian perspective) and long-term studies to ultimately improve communities' living conditions and resilience. Combining architectural and humanitarian perspectives (Charlesworth, 2006), the detailed contextual information of the built environment captured using advanced recording technologies can inform both short and long-term actions in post-earthquake scenarios by engaging with target communities towards their meaningful participation (Davidson *et al.*, 2007), being cost-efficient in the long term compared to traditional forms of surveying.

Research methods

The methodology proposed combines the latest advanced recording technologies for obtaining the building's metric data and interviews to complement that with social information in the pilot case study of Bela, a representative example of a historical settlement within the seismic region of Kutch in Gujarat, India. Beyond the first stage of data capture, the methods also include the utilisation of the information obtained for community engagement, understood as a respectful way of working with local people to incorporate them in the understanding and assessment of their built heritage and previous reconstruction processes after earthquakes, towards developing preparedness for future seismic events.

This approach builds from existing literature (Desai, 2019) and is based on the research team's previous experience (see acknowledgements). The method sits alongside scholarly work in the field that discusses local community involvement in post-disaster contexts. For example, Shaw and Sinha (2003) show how people-driven initiatives were more effective in disaster management for the Bhuj 2001 earthquake. The work by Johnson *et al.* (2018) and especially Chandani *et al.* (2019), in the context of the 1994 Phojal Nalla floods in the Indian Himalaya and the 2015 earthquake in the Kathmandu Valley in Nepal, respectively, further demonstrate the importance of the sustained engagement of affected local communities through their cultural heritage in post-disaster recovery processes to ensure their resilience. Similarly, Jigyasu (2013) argues about the importance of considering communities in the aftermath of an earthquake, where decisions will have a long-term impact on the sustainability and the conservation of cultural heritage in affected villages.

Research objectives

This paper is part of a larger research project, which aims at (1) documenting the settlement and buildings with a high level of detail to allow damage assessments, informing a strategy towards damage mitigation and repair instead of complete replacement; and (2) understanding documentation as a process of engagement and participation with the community, towards the development of a methodology that goes beyond the mere application of technological means for heritage documentation but aims at involving the residents of the village in every step of the way. Seeking acceptance and active participation will, in turn, help to mitigate the risk of future earthquakes by developing awareness and preparedness locally (Plate 2). The paper focuses on the second aim, from which it contributes to the overarching research purpose of developing a sustainable *re-construction* [1] methodology for seismic-prone areas of Gujarat, India, which integrates technical and social datasets, collectively representing the reality of the affected areas, people and material culture (Devilat *et al.*, 2022).

Methods deployed

The methodology combines different recording tools to capture social and built environment data, such as interviews, mapping, drone capture, photography, and 3D laser scanning in Bela (Plate 3). The aim was not only to focus on the current condition of the buildings but also to understand previous reconstruction processes, for which the conversation with the residents – current and migrated – was crucial, as the latest earthquake that affected the area occurred more than 20 years ago. Particularly in terms of relating to the local community, social surveys were applied, plus semi-structured social interactions around visual evidence of the captured data, at a second stage, as explained in the following pages.

The methodology was informed by previous research, adapted locally, and implemented through an institutional collaboration between the universities involved and the Hunnarshala Foundation. This regional non-profit organisation works closely with communities to improve construction practices (see acknowledgements). CEPT University collected data, while this

Source(s): 3D for Heritage India Research Project. Authors: M. Mane and Z. Pithawalla

Plate 2. Team members explain the research's purpose to the residents of Bela and the 3D laser scanner capturing data on-site. July 2021

Plate 3.
3D laser scanner capturing data on-site. July 2021

Source(s): 3D for Heritage India Research Project. Author: Z. Pithawalla

regional non-profit organisation engaged in continuous community engagement. This institutional collaboration was one of the project's key factors.

Selecting the site

To define the case study, a reconnaissance trip was carried out in February 2021 by the research team along with the local project partners (Devilat *et al.*, 2021). Eleven villages (three of them seen in Plate 4) in the seismic-prone zone of Kutch were selected: Bela, Depa, Jadva, Kotdi Mahadevpuri, Moti Khakhar, Moti Reha, Nani Reha, Nani Tumbadi, Roha, Tera, and Vrajvani. These villages were then compared based on their accessibility, the number of houses reconstructed, the status of existing constructions, the presence of heritage assets, previous records, the community still residing in the village and their recollection and memories of the Bhuj earthquake, which severely affected the area in 2001 (7.7 M_w magnitude). In most cases, conversations with community representatives were held to understand their potential interest and support. The decision was to focus on Bela, where that earthquake damaged most houses but did not completely collapse and where the community was keen on participating.

Introducing the case study: Bela

Bela, roughly 170 km northeast of Bhuj, has an area of 85 square km and a population above 4,000. The village is situated between the major fault lines of the Kutch region and lies around 90 km northeast of the epicentre of the 2001 earthquake. Bela's built heritage assets are an old fortress (Darbargadh), religious temples, memorial stones and around 800 traditional domestic structures.

Bela was an important village in the region; however, the major earthquake of the Rann of Kutch in 1819 seems to have played a significant role in Bela's decline throughout history. With a magnitude of 8.0 M_w (BMTPC, 2010), it changed the geography of the whole region. After this event, the watercourse near Bela dried (only having water during the Monsoon season), leaving Bela without connection with the sea through the Rann of Kutch leading into the Gulf of Kutch. Other earthquakes affected the village in 1846 and 1956 in Anjar, 7.0 M_w (BMTPC, 2010). The last significant disruption was the Bhuj earthquake in 2001 (7.7 M_w), from which the settlement has not entirely recovered.

Research results

Documenting the built environment

The physical realm's documentation was based on terrestrial 3D laser scanning, drone surveying and photography. In 2021, a short time frame of five days was defined to simulate an emergency post-earthquake scenario, and a large area of Bela was captured. Initially, the village's building stock and types of streetscapes were visually analysed. Preparatory work included the creation of a base map planning the tentative locations of scans, procuring support tools and equipment to facilitate the on-site data collection during scanning, and developing an information leaflet of the project in the regional language to have informed conversations with the communities regarding how the data will be collected and its purposes. This was especially relevant considering the novelty of capturing visual data with a 3D laser scanner and a drone and the need to access interior spaces to document them. These technologies capture everything in sight, raising potential privacy concerns that have been addressed throughout the research project in this manner. An expert on-site safety assessment of the open spaces and structures to be scanned was also considered, which is critical in actual post-earthquake scenarios (ICCROM *et al.*, 2022). It is essential to highlight that 3D laser scanning is a fast and comprehensive surveying method, which only requires operators to spend a short time in a potentially hazardous structure. The laser can measure spaces without the need for human handling, besides the scanner's positioning. Each scan can take around five minutes, so it is considered a safe survey method compared to other traditional techniques applied in post-earthquake contexts, such as hand-measuring (Devilat, 2013).

The sequence of documentation entailed interactions with the village communities, including detailed conversations with the specific property owners of the 18 buildings

Source(s): 3D for Heritage India Research Project. Author: M. Mane

Plate 4. Glimpses of the construction typologies in three of the 11 potential villages identified during the reconnaissance field trip. From left to right: Bela, Roha and Moti Khakhar. February 2021

identified for interior scanning (Plate 5). This ensured their understanding of how the technology operates and an ethical approach that will be further discussed in this paper. The interior spaces captured were connected by scanning the village's primary lanes, covering Bela's central and historically relevant area. Drone mapping was used with photographs and videos, capturing the same area as the scanner, complementing the terrestrial information.

Houses identified by the survey team in each neighbourhood represented diverse social and economic groups. The identification of houses started with informal interactions with the villagers, finding out which traditional houses have survived, or been repaired and reconstructed post-earthquake. Based on this information, the team conducted a visual survey of the potential houses and checked the willingness of the occupants/owners to participate in the digital documentation. The scanning process of individual buildings was initiated after informed consent was obtained from the concerned community members.

The exterior scans were mainly taken in black and white to expedite the on-site data capture, while the interior scans were taken in colour. The main challenges were to keep the scanner's working temperature within its tolerance range (up to 55 °C) in the harsh desertic climate, protect the equipment from cattle and animals, manage the curiosity of the village inhabitants, and undertake data backups in an area with low connectivity.

The 3D model obtained is formed by combining the individual scans (a process known as registration), which included most of the selected settlement's area, considering public spaces and 18 buildings scanned interiorly (twelve houses, three religious buildings, two shops, and one storage space). The 3D model (Plate 6) is highly advantageous due to its capacity for developing a series of architectural visualisations and establishing a precise basis for architectural intervention and design. Further, the existing physical conditions regarding geometric and visual information are free from errors and deviations, with no subjective bias or inaccuracies in survey measurements. The details captured allow the analysis of how spaces are inhabited, and the interviews complement it (Plate 7). The scanning method offers a seamless (and accurate) transition between exterior, intermediate and interior spaces, which is usually challenging when using manual documentation. The 5-day fieldwork confirmed the possibility of capturing and being able to visualise a large portion of a settlement with the same millimetric level of detail as a single building. A 900,000 m^2 area was covered with 324 scans and 560 aerial photographs and videos done by the local India team, remotely supported by the UK team due to COVID-19 restrictions in place at the time.

The 3D laser scanning dataset provided all-time accessible evidence to assess the overall conservation state of the documented structures. For example, the internal and external data of an old Chabutra (bird feeder) affected by the 2001 Bhuj earthquake allowed for identifying, with detail and precision, specific bulges and deviations not evident to the naked eye, which helped establish the building's safety. However, further site visits may be needed to assess reinforcement strategies in case a long time passes from the initial record, to check if the structure has further deteriorated or changed from the moment of data capture.

Documenting the social and cultural environment

As mentioned earlier, the first approach to community engagement was made during the reconnaissance trip to inquire regarding the residents' interest. The second approach consisted of semi-structured interviews conducted in preparatory stages and during the 3D data capture. The interviews were mainly associated with the 18 buildings interiorly documented in 3D (Table 1). The interviewees represented five traditional neighbourhoods in the village, each corresponding to one specific community, most located in the historical area (Plate 8).

Source(s): 3D for Heritage India Research Project. Authors: M. Mane and Z. Pithawalla

Plate 5.
Photos of the buildings selected for interior scanning in Bela. July 2021

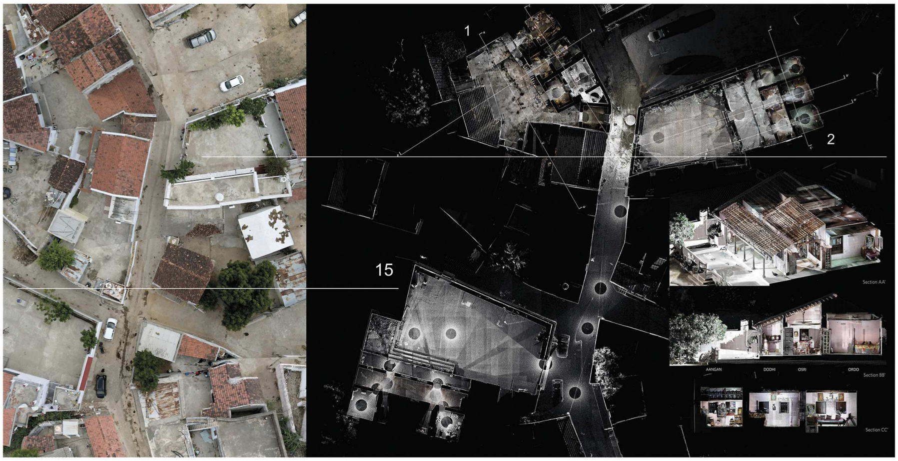

Plate 6.
Aerial drone photography and detail of LiDAR survey plan (plus architectural projections) of the same area in Bela. 2021

Source(s): 3D for Heritage India Research Project. Authors: B. Devilat and F. Lanuza, based on data obtained on-site by M. Mane and Z. Pithawalla

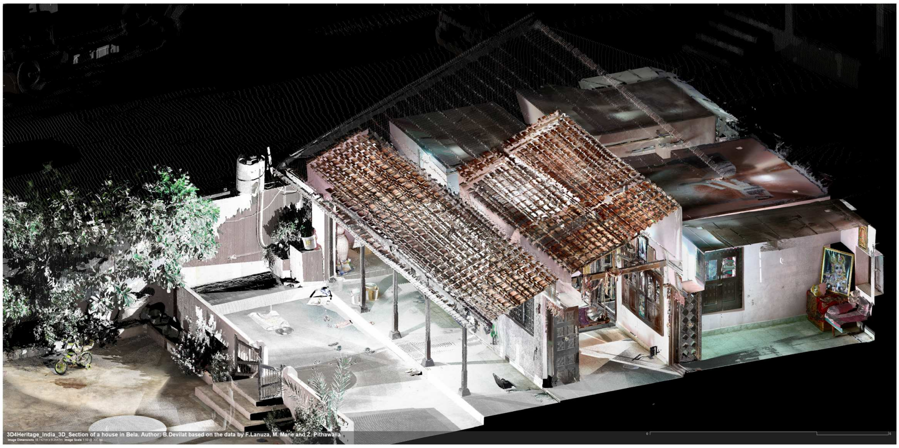

Plate 7.
Section of dwelling number 2, where the details captured by the 3D laser scanner can be appreciated. 2021

Source(s): 3D for Heritage India Research Project. Authors: B. Devilat and F. Lanuza, based on data obtained on-site by M. Mane and Z. Pithawalla

Few structures were abandoned, or the owners migrated from the village. For such structures, secondary information was acquired from either neighbours or relatives. Cultural considerations were incorporated by the analysis of the interviews, for example, inquiring into historical and social aspects of the village whilst observing modes of living and the use of spaces. At a household level, surveys inquired about (1) the spatial arrangement of houses belonging to a particular family group, (2) the changes in those buildings and spaces through time, (3) changes in preferred construction materials and methods, (4) the 2001 Bhuj earthquake's impact considering efforts to make houses earthquake-resistant, and any relief or training received by NGOs or the Government, and (5) the desired house type and

Table 1. Structures interiorly scanned and interviews carried out in Bela

Structure No.	Type of usage	Type of ownership	Number of floors	Type of materials	Completeness of data	Community/ Neighbourhood	Occupied	Diversity of building elements	Visibility of damage	State of conservation	Social survey information (about family)
1	Residential	Private	Ground floor + partial first floor	Stone, Timber	75	Darbar	Yes	High	Yes	Fair	S1
2	Residential	Private	Single Storey	Stone, Timber	95	Darbar	Yes	Med	No	Good	S2
3	Not in use (Commercial usage in past)	Private	Single Storey	Stone	95	Darbar	No	Low	Yes	Poor	–
4	Social	Public-Private (Chabutra, bird feeder)	Single Storey	Stone, Timber	95	Darbar	No	Low	Yes	Poor	–
5	Religious + Residential	Private	Single Storey on high plinth	Stone, Timber	80	Darbar	Yes	Low	Yes	Needs attention	S5
6	Residential	Private	Single Storey	Stone, Timber	90	Khatri	No	Low	Yes	Fair	S6
7	Commercial	Private	Single Storey	Stone	90	Darbar	Yes	Low	Yes	Fair	–
8	Commercial	Private	Single Storey	Stone	80	Darbar	Yes	Low	Yes	Needs attention	–
9	Residential	Private	Single Storey	Stone, Timber, Mud mortar	90	Meghwal	Yes	Med	Yes	Good	S9
10	Residential + Workshop	Private	Single Storey	Stone, Timber, Mud mortar	100	Kumbhar	Yes	Med	Yes	Good	S10
11	Residential + Workshop	Private	Single Storey	Stone, Timber, Mud mortar	90	Kumbhar	Yes	Med	Yes	Good	S11

(*continued*)

Table 1.

Structure No.	Type of usage	Type of ownership	Number of floors	Type of materials	Completeness of data	Community/ Neighbourhood	Occupied	Diversity of building elements	Visibility of damage	State of conservation	Social survey information (about family)
12	Residential	Private	Gr	Stone	75	Darbar	Yes	High	Yes	Fair	–
13	Not in use (Residential usage in past)	Not known	Single Storey on high plinth	Stone	90	Darbar	No	Low	Yes	Ruins	S13
14	Residential	Private	Single Storey	Stone, Timber	70	Darbar	Partially	Low	Yes	Good (One structure in the cluster is in ruins and presently not in use)	–
15	Residential	Private	Single Storey	Stone, Timber, Precast cement columns, Cement Plaster	80	Darbar	Yes	Med	No	Good	–
16	Not in use (Residential usage in past)	Private	Single Storey	Stone, Timber	75	*Vaniya*	No	Low	Yes	Ruins	–
17					50	NA	Partially	Low	No	Fair	
17	Residential	Private	Ground floor + first floor	Stone, Timber, concrete in parts	80	Darbar	Yes	Med	Yes	Good	–
18	Religious + Residential	Private	Single Storey on high plinth	Stone, Timber	80	Darbar	Yes	High	No	Needs attention	S5

Author(s): M. Mane, J. Desai, A., Singh and T. Choudhari, July 2021 Source: 3D for Heritage India Research Project

Source(s): 3D for Heritage India Research Project. Authors: B. Devilat and F. Lanuza, based on data by A. Singh, M. Mane, J. Desai and T. Choudhari

Plate 8. Plan of Bela, mixing the aerial photograph with the 3D laser-scanned area (in white), indicating the casts present in the central area of the village and the buildings documented. 2021

materiality/building methods. At a settlement level, the conversations with the community attempted to cover (1) the development and decay of the settlement over time and its historical disruption, and (2) the physical impact of the 2001 earthquake and the related awareness and memory in the different castes of the village. Male family representatives were interviewed directly, with some vocal female members also consulted by the team to cross-check the information. The collected information was then transcribed and mapped spatially. This approach helped the team understand how extending family relationships defined a seemingly organic and additive self-constructed growth of housing complexes throughout time.

A brief history of Bela (as told by its people)

Through conversations with locals about their village, the history of Bela can be outlined and better understood. Bela was a prosperous trading settlement in the Sindh belt, an area that fell under India's rule after the partition between that country and Pakistan in 1947. This political division caused a severe disruption in the village's trade and social networks. The trade—from then on across a national border—continued between Bela and the city of Nagarparkar in Pakistan. However, it came to a complete halt after the Indo-Pakistani war in 1977, triggering outmigration due to a lack of business opportunities. For example, most fabric block printers have moved away to other towns and cities, although they come back to Bela to visit occasionally. People have also continued to migrate from the village due to weather patterns, with droughts becoming more frequent in the last 30 years, affecting agricultural trade.

As a result of the earthquakes that have affected Bela during its history, which generated disruptions and outmigration, the interviewees said they had stayed in the walled settlement and around its peripheries. However, only the following have an actual presence in the village: Darbar predominantly, Meghwal and Koli – mainly cattle rearing communities who are also engaged in building activities; with minor presence of the Bhil (tribal farmers), Brahmin (priests and teachers), Kumbhar (potters) and Rabari (cattle rearers/herders). Houses abandoned by other castes or communities are occupied mainly by Darbars or abandoned and dilapidated. The village's Darbar socio-political and economic leadership remains in place today. These communities were mapped on top of the 3D data obtained, revealing a socially divided settlement that challenged the engagement activities as unified workshops for all the residents (Plate 8).

Reflections on community engagement

Two distinct yet complementary ways of a documentation survey were deployed to engage with the local community actively. First, as a precursor and complement, before and during the capture. Second, after the data was obtained and processed, to ensure complete understanding and validation of the data obtained, in response to the ethical challenges that exist between those knowing the extent of the record *a priori* (the researchers) and the local community as occupants of the building recorded, who were new to the technology and its outcomes. Visualisations were therefore developed as a tool to engage with them, bringing local insights into the documentation process. This allowed the team to analyse ways of inhabitation based on the interior spatial configuration and ensured people's understanding of the record obtained and the expected uses of the processed data (Plate 9).

Two considerations can be drawn from this experience. The first is how strange it was for people in Bela to have their own places of day-to-day life represented and objectified through sophisticated visual means. The immediate, familiar relation usually held with their environs was replaced by a mediated relation in which they had less control and understanding, demanding guidance and adjustment. As a second consideration, community engagement is needed in the long term to build up trust and greater benefit. Thus, engaging with locals in a post-earthquake scenario implies a further challenge. As these two processes often work diachronically, there is a need for institutional continuity between the post-earthquake assessment and recovery and the culture-led risk mitigation process. This continuity, in turn, implies consistent leadership and organisation at a local community level.

Both approaches to community engagement ensured a two-way knowledge transfer as the team increased their comprehension of the village's living culture, and villagers understood the 3D laser scan tool, the obtained data and its possibilities as an earthquake recovery and mitigation. This mixed strategy of complementing the built environment data captured with the scanner and drones with interviews and community engagement activities enables continuity and compatibility between modern techniques and all-encompassing rural culture, such as in the case of Bela, for the social acceptance and introduction of *re-construction* approaches aiming to

Plate 9.
Perspective section of dwelling number 1, showing the interior spaces. 2021

Source(s): 3D for Heritage India Research Project. Authors: B. Devilat and F. Lanuza, based on data obtained on-site by M. Mane and Z. Pithawalla be culturally relevant and sustainable in the long term. Nonetheless, any study of material culture based on 3D laser scanning data would need a degree of on-site observation and engagement with local people that goes beyond the specific (sometimes narrow) moment reflected in the data capture, which could, in turn, inform and enhance a qualitative study with a detailed and precise quantitative basis. The possibility of a deeper understanding of the values of such heritage marks the importance of this form of documentation as a technical basis for repairing and retrofitting buildings, especially when focused on domestic heritage.

In Bela, the second engagement stage took the form of an informative workshop and exhibition, along with an open conversation with the community, at the Market Square's centrally located open public space, aiming to be as inclusive as possible (Plate 10). However, that space is dominated by men, and women usually refrain from going to these public spaces, especially when men occupy them. Thus, the programme was adapted so the exhibition could be displayed the next day alongside various activities in one of the village's temples to ensure women could also see and engage with the material and have their voices and insights included. The enclosed space of the temple premise facilitated open discussions between the researchers and women. The visuals of digital data triggered conversations about the memories of the places and how these places are used in everyday life (Plate 11). The overall reception from the local community revealed intrigue regarding the aspects of their village that the research team found worthy to document. This has led to them discussing the most relevant built structures, the stories behind them and searching for avenues to intervene in them towards their physical conservation.

The display of outputs based on the data collected included interactive material to better engage with different community members, including children. A further way to make the overall work more accessible was to rely on a map using aerial photographs and videos from the drone capture. This helped bridge the gap in the research team by explaining the technicalities of 3D laser scanning to the community. Seeing how the local community interacted with this aerial map was interesting. First, they tried to understand and locate

Source(s): 3D for Heritage India Research Project. Author: B. Devilat

Plate 10.
Team members at the Market Square exhibition. November 2021

Plate 11.
Team members at the activity with women when exhibiting in Bela. November 2021

Source(s): 3D for Heritage India Research Project. Author: Z. Pithawalla

their homes within their broader village context. Then, they related the map to the laser scan data images, orienting their understanding through their homes and other prominent village landmarks identified using the aerial map (Plate 12). This is relevant as a starting point when working with historical areas; a greater understanding of the representations can be achieved if starting with what is known and familiar.

For each of the 18 buildings interiorly surveyed, a series of architectural projections from the data were created: 3D views, plans, elevations, sections, and aerial views, compiled in a booklet that was given to each owner or carer of those buildings and used to have conversations with them about the record, the possibilities for understanding the spaces and the potential risks associated in some of them (Plate 13). When not present in the activities, the team delivered the booklet to as many surveyed houses as possible in the local community for them to see the records of the village and their own homes, discuss them and keep a physical copy for future reference, understanding that digital versions are inaccessible to most people in Bela. In this way, it was intended to address an imbalance observed in the first engagement through interviews, where men came forward as family leaders and representatives, and the Darbar caste was over-represented in comparison with other groups.

Visual representation is key for a more direct apprehension and interpretation of the record, which, combined with playful methods, can further stimulate engagement. In this case, jigsaw puzzles worked as a tool to capture the children's curiosity (Plate 13). They were a challenge to the children, as who could solve them in the least amount of time. They started seeing a photograph, a map, or 3D point cloud data and relating that information spatially to the rest of the village map exhibited and the other pin-up sections to identify the data they wanted to understand. In some critical cases, such as buildings with severe damage yet still inhabited, the representations were used to have additional conversations with the occupants in further visits to the village to suggest safer internal arrangements and possible evacuation routes in the event of an earthquake. For example, in the case of a Darbar temple with a damaged wall posing risk (Plate 14), temporary alternative sleeping arrangements suggested

Source(s): 3D for Heritage India Research Project. Author: B. Devilat

Plate 12. Residents identifying known buildings on the aerial map of Bela at the Market Square exhibition. November 2021

Source(s): 3D for Heritage India Research Project. Authors: B. Devilat and Z. Pithawalla

Plate 13. Discussing the 3D laser scanning output with the local communities through booklets compiling the records of each house (left) and children engaging with jigsaw puzzles (right) in the exhibition at Bela. November 2021

by the team were disregarded due to privacy-related concerns associated with cultural aspects. However, the owners addressed these urgent safety aspects by rebuilding the damaged wall a few months later.

An important consideration about language is also relevant to mention as part of the activities carried out. Spoken and written language can pose a difficulty in explaining the 3D laser scanning survey, its extent, and what can be further done from it. Hence, a careful,

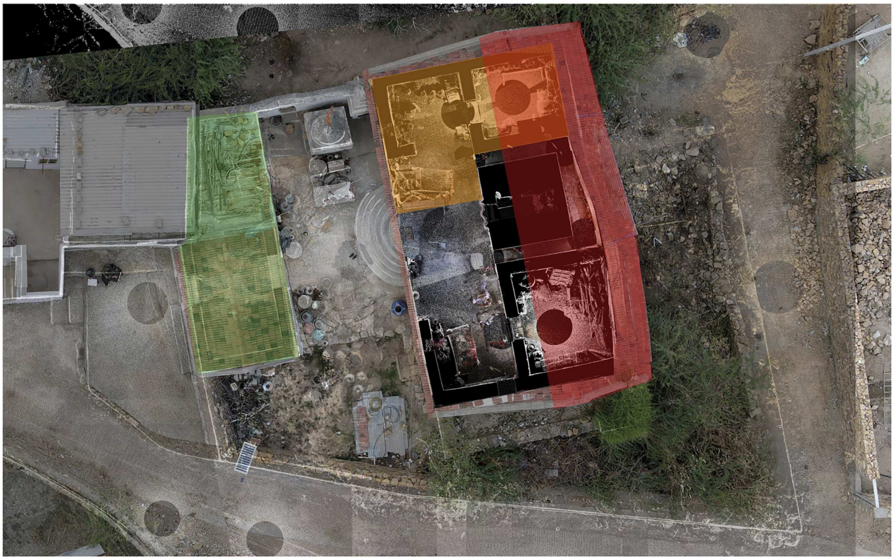

Plate 14.
Plan of a family temple in Bela combined with its aerial photography. The access spaces are marked in green, as potential temporary rooms in better structural condition than the ones occupied at that moment (orange). The most damaged and unsafe area is marked in red. July 2021

Source(s): 3D for Heritage India Research Project. Authors: B. Devilat and F. Lanuza, based on data obtained on-site by R. Khatri, A. Desai, M. Mane and Z. Pithawalla

guided display of the visual outputs became relevant to effectively and meaningfully reach the villagers. For example, Gujarati does not have a direct translation for terms like "heritage and conservation". This language gap added to the cultural and knowledge gap, resulting in long conversations to address a simple explanation of the work and how the technology was used. Visual representations are essential in this regard as a way to bridge the language gap, as well as the involvement of local actors, such as local academic institutions and NGOs. Each of them was carefully created for daily objects to be visible and recognisable, as those were the anchor points to start the conversations. For example, a recognisable building element, a piece of furniture or a decoration, especially for more abstract visualisations, such as plans or sections.

Discussion and conclusions

This paper accounted for and reflected on the process of engagement with Bela's residents as the first implementation of the proposed documentation methodology, which can inform the conservation of a more significant number of vernacular dwellings and the understanding of post-earthquake *re-construction* as a process that engages with built heritage and its communities in a broader sense.

The social engagement also revealed Bela's oral history, a brief outline of which is published here for the first time. It provides insight into how it has changed throughout the centuries due to previous earthquakes and political events. The 3D record obtained allowed for jointly discussing the attributes of people's homes and villages, bringing in their insights and history of occupation. In this regard, local academic institutions and NGOs are critical mediators in reaching the communities in greater depth, from which to bridge to external and governmental agencies based on existing links and trust. This is key for developing awareness and preparedness for future seismic events, which is a practical and social implication of carrying out case study-based research.

The representational aspects of the survey to engage with the inhabitants helped to discuss their sociocultural identity and understanding its value in a new light. This certainly favoured trust and their openness to further work, but also revealed a degree of disparity in the levels of understanding of the extent of the data captured and its potential use. Thus, planning and adapting the on-site work with these ethical considerations in place is relevant, for example, with opportunities to show the preliminary results to the communities to ensure their acceptance.

Another critical aspect found is that cultural considerations and attitudes are as important as the records of the buildings in terms of earthquake mitigation when it comes to safety implications, as per the latest example. This marks the importance of any safety measures deriving from the record to be socially shared and culturally appropriate, seeking suitable alternatives.

Like in any other study, there are limitations. Social divisions (caste, gender) also implied disparity in terms of accessing the data and relating it to the research team, bringing forward the need to tailor and adapt public engagement to achieve inclusivity, as shown. The overall experience also brought forward a sense of awareness in the community regarding the need for preparedness in the face of earthquakes. There are also technical challenges in using advanced recording technologies in terms of equipment accessibility, knowledge and skills, and future uses of the data. These have been addressed through a parallel research and knowledge development project with the local academic partners [2]. However, it might be challenging to replicate the methodology in other international cases.

The detailed representation and visualisation of the surveyed buildings enhance the possibilities of future planning and risk mitigation strategies with a participatory focus (such as the assessment of structures, evacuation routes, possible repairs and reinforcements), which have informed the development of a framework towards the *re-construction* and mitigation of seismic-prone heritage areas of Gujarat, part of a broader research project. Therefore, the capture, post-processing and work from the collected data are contextualised in that project's proposed institutional framework, including local communities, NGOs, academia and governmental authorities, aiming to propel its replicability and scalability. This paper in particular discusses the related community engagement aspects [3], which the authors believe are vital for this framework to have a positive economic impact, optimising resources and minimising costs associated with the effects of an earthquake - but this can only be effectively demonstrated by implementing it at a larger scale, in an actual post-earthquake situation. As a step in that direction, experiences of training and education of present and future Architecture and Heritage Conservation practitioners have been led by our partners in the context of this research project and beyond.

Finally, the mixed-documentation methodology proposed here can potentially benefit similar historical settlements in India and elsewhere. Understanding the study and response to earthquakes is a learning process for building up risk preparedness and informing a holistic, sustainable, and resilient *re-construction* of non-monumental heritage driven by a people-centred approach.

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Ethics: This research obtained ethical approval at Nottingham Trent University, to carry out the interviews and field works as outlined in the text. Informed consent has been sought at all times in accordance with the university's guidance.

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Credits for images and videos from 3D laser scanning: Bernadette Devilat and Felipe Lanuza, using the 3D data obtained on-site by Mrudula Mane and Zeus Pithawalla, with the support of Jigna Desai, Aditya Singh, Tanvi Choudhari and Sukrit Sen. Videos available on the project's website and at: https://vimeo.com/644834342 and https://vimeo.com/737568146

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Credits for photographs: Mrudula Mane, Bernadette Devilat and Zeus Pithawalla.

Notes

1. *Re-construction* is understood beyond rebuilding 'as before' but as a set of strategies that include repair, reinforcement and re-use whenever possible to conserve a greater number of built heritage buildings (Devilat, 2021).

2. "Surveying Heritage Buildings in Ahmedabad, India: Empowering Local Action and Skills for Heritage Conservation". More information here: https://ntu3dscanlibrary.wordpress.com/

3. The research project from which this paper derives has had three phases. In the first two stages, a framework was developed and published as a Policy Brief. The technical aspects of 3D digital

documentation applied to post-earthquake contexts were covered in a practical guide. The latest phase (three), studied the applicability and scalability of the framework proposed, including the development of a Disaster Risk Management Plan and the reinforcement of one building in Bela as a tangible example of repair strategies designed using the 3D laser scan data. This paper accounts for phase one of this research project (2020–2021) and focuses only on the participatory aspects implemented with the local communities during and following the first data capture. Phases two and three, which are more related to the impact of the project, will feature in coming publications. For updates please visit: www.3D4heritageindia.wordpress.com

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