Computational Design for Resilient Shelter

Project Survey Report

South Sudan

State-of-the-Art on Flood Resilient Shelters




STRUCTURAL XPLORATION LAB

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ABSTRACT

One of the most observable consequences of climate change is the abrupt increment in the number and intensity of seasonal floods. This has a special impact on vulnerable communities and developing countries that experience a strong impact on their housing infrastructure, leading to the displacement of communities on a seasonal basis. As a consequence, there is an imperative need for developing flood resilient solutions for housing in flood-prone areas. Therefore, this report presents the results of a comprehensive analysis of the current literature on flood resilient solutions so as to provide the basis for further research and development on the topic. Academic and practice reports were covered, aiming at providing a wide glance over the current developments on flood-resilient housing. The main aim of the work presented in this report is to provide an extensive review of constructions solutions developed to deal with seasonal floods, as well as common materials and detailings to reach such an objective. Besides, this document aims at presenting a first general glance to researchers and practitioners before developing specific solutions for a given region, acknowledging that due to cultural and material constraints, one-fits-all proposals are not a realistic solution in humanitarian scenarios.

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1. INTRODUCTION

The recent increase in climate change impacts has proved to be more threatening to developing economies when compared to developed societies. This is mainly due to the feeble adaptation ability and response capacity, making third-world countries extremely vulnerable to recurring natural disasters. Given its particular geographic location and topography conditions, South Sudan has been dramatically affected by the increase in flooding over recent years, posing a challenge to several regions across the country. For instance, the Greater Horn of Africa Climate Outlook Forum (GHACOF) reported that South Sudan experienced above-normal rains during the 2012 rainy season, which led to flooding that in some parts of the country prompted displacement of thousands of households [1].

In the local context of South Sudan, floods have a significant impact on the population's day-to-day life, considerably affecting housing, crops, cattle, roads, health facilities, among others. Communities have adapted to the yearly recurring floods by adopting a nomadic lifestyle, which implies moving to higher lands when the water level rises beyond a sustainable limit. Nevertheless, as settlements expand and more infrastructure is developed to satisfy basic requirements and needs, periodical displacements have an increasingly negative effect on the well-being of developing communities, especially if large reconstruction projects should be carried out after every flood season to bring houses and shelters back to its normal functionality.

Undoubtedly, houses and shelters are the most affected assets during floods for the communities in South Sudan. However, the development of a flood resilient housing culture across the country is disrupted by the inherent constraints in materials availability, skills, construction tools, funding for imported building components [2], and the defective conditions of the national road network [3], posing a complex scenario for a smooth operation of the different supply chains. The magnitude of the problem is amplified by the scale of the floods across the country, leading to about 1 million people affected every year and with the trend towards more regular and more destructive floods [4].

Given the pronounced need for a flood resilient housing culture in South Sudan, new construction solutions are required to tackle this ongoing and increasing problem across different regions in the country. As a first step towards such a goal, this report presents a review of the state-of-the-art regarding flood-resilient techniques and approaches, so as to provide a thorough overview of current developments in the field. The main aim of the work presented in this report is to provide an extensive review of constructions solutions developed to deal with seasonal floods, as well as common materials and detailings to reach such an objective. Besides, this document aims at presenting a first general glance to researchers and practitioners before developing specific solutions for a given region, acknowledging that due to cultural and material constraints, one-fits-all proposals are not a realistic solution in humanitarian scenarios. The following sections present the methodology employed in this survey, as well as the main results found in academic and practice applications.

2. METHODOLOGY

Seasonal floods are a common problem in many regions around the globe. While the source of the flood may vary (heavy rain, tsunamis, hurricanes, among others), the solutions adopted to develop flood resilient constructions share common grounds in terms of their functionality and final goal. In order to properly conduct a literature review that envisions the whole spectrum of current solutions, a systematic analysis of the available information on flood construction was carried out regardless of geographic location, flood source, materials employed, cost of implementation, required tools and skills, cultural constraints, and durability. Besides, to better systematize the analysis, the sources of information were classified into academia and practice.

Academic sources embraced all information published by universities, research centers, and laboratories. Therefore, the literature review classified into this category comprised reports, journal articles, and conference proceedings. The information and documents were gathered from indexed databases by employing keywords related to the topic under analysis (i.e., flood shelters, water resilient construction, amphibious houses, etc), after which the results were manually filtered to keep only the ones related to flood-resilient construction and to eliminate any duplicates related to a same project. Results were not filtered by location or background, allowing all academic and research-based proposals into the final analysis.

Practice sources comprised all the reports and handbooks published by non-governmental organizations, governmental organizations, practitioners, and private entities. Therefore, organizations such as the United Nations, Shelter Cluster, the Common Humanitarian Fund, the International Organization for Migration, and others, were consulted during the information collection. The documents were gathered from the official websites of the organizations, indexed databases, and private databases of the members of the team. Subsequently, a systematic review of each file was carried out to extract the information relevant for flood-resilient construction. The following sub-sections present the results from the literature review in each category.

3. RESULTS

3.1. STATE-OF-THE-ART: ACADEMIA AND RESEARCH

Due to its potential to mitigate social crises during natural disasters, flood resilient construction has been in the sight of academics and researchers during the last few decades. Two main strategies can be identified in the literature to reduce flood damage and impact: passive systems and active systems. Passive systems are flood control strategies whose operation does not need an increase in water level to get activated. Examples of these systems are permanent static elevations, flood proofing, or water-resistant foundations. On the other hand, active systems require an increase in the water level to start operations. The most extended examples of such an approach are buoyant solutions.

The National Building Research Organization in Sri Lanka proposes two intuitive and practical solutions for permanent static elevations [5]. First, a raised floor where the ground level is elevated by increasing the plinth. The plinth height shall be a minimum of 150 mm above the highest recorded flood level in the region. Besides, additional protection is required in the raised plinth to prevent it from erosion. Second, a construction on stilts where the posts shall be raised up to a minimum of 150 mm above the highest recorded flood level in the region. Besides, it is recommended that the maximum unsupported height of stilts shall not exceed 3 m. Otherwise, an intermediate tie-beam shall be provided. Navas et al. [6] propose an initial design and analysis for fast rehousing of people affected by floods, highlighting that efficient flood preparation is needed to minimize the damage in flood-prone areas. The conceptual design proposes a floor elevated solution employing 1.5 m stilts and a concrete foundation. This latter limits the application of the solution in rural areas, but the structural analysis showed the need for strong foundation piles to take both vertical and horizontal loads. Results show that for a 50 m^2 house, the required construction time is only about 15-20 days, assuring flood resilience over the life span of the house.

Gautam et al. [7] remarks that raised plinths are also common in vernacular construction, where materials other than concrete can be employed for the foundation, as shown in Figure 1. After a comprehensive survey across Nepal, the authors found that flood resilient vernacular construction commonly employs an elevated platform built on top of wooden posts, providing stability and resistance against earthquake loads. However, it is highlighted that employing wood for the foundation might require periodical maintenance if there is a constant presence of water. Likewise, special care needs to be taken along the design process to avoid overturning of the structure, especially if the raised height goes beyond 1.5 m (see Figure 2). Similar results have been found in other locations around the globe for flood-prone areas [8–11].

(a) (b)

Figure 1. Common vernacular elevated construction: (a) Jhapa, Nepal [7], and (b) Warrap, South Sudan [10].

The design and detailing processes of elevated houses are straightforward and have been validated by previous applications worldwide. However, its widespread adoption might be constrained by the local conditions of the communities. For instance, ACTED [10] reports that, in the Warrap region in South Sudan, elevated shelters are not a common solution among communities due to the considerable amount of wood required to support the massive mud walls of tukuls, as shown in Figure 1(b). It highlights the potential to develop engineered elevated solutions that achieve more economical structures and provide proper bracing against lateral loads. However, the variability in the mechanical properties of locally available materials makes it difficult to provide a general solution, and therefore, each construction must be considered separately depending on the materials at hand as the methods currently used [10].

Figure 2. Elevated houses in the Gulf Coast, Canada [12].

Another widespread passive solution against floods is flood-proofing. The main function of flood-proofing is to prevent extended damage to the house in the event of high-water levels. Flood proofing can be classified as dry and wet, as shown in Figure 3. Dry flood proofing is an approach that involves building permanent or temporary barriers such as levees, dikes, door seals, or sandbags, leaving the house intact and dry in the event of floods. Since dry flood proofing requires maintenance, it can draw issues and is an overall expensive measure that often is not possible in the context of emergency housing. Dry flood proofing is not also appropriate where the flood depths can be high [8]. Several applications of this approach can be found worldwide [13–17]. On the other hand, wet flood proofing allows the water to get into the house while avoiding water loads to build in the external walls which can cause structural damage and collapse of the house. After inundation, flooded houses only need quick repairs and cleaning, and can be reused in a short period of time after the flood. Designing walls, doors, and windows to resist hydrostatic forces that eventually can increase due to the rise of the water level is costly, particularly when flood events are rare [8]. The best option for this scenario is to allow the water to come inside the house, balancing the hydrostatic forces in a wet flood proofing approach [18].

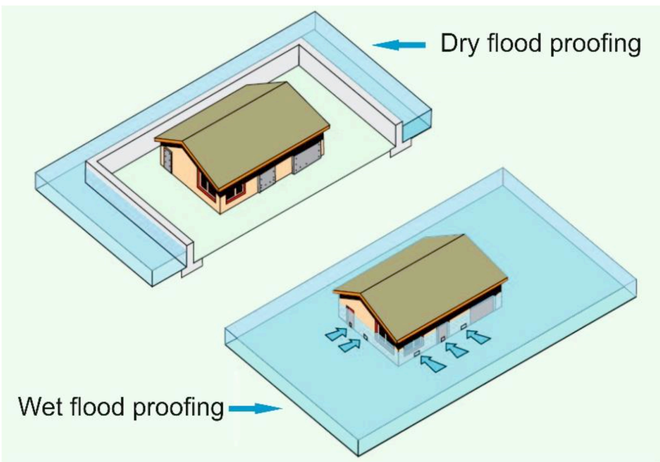


Figure 3. Dry and wet flood proofing approaches [8].

Due to their simplified detailing and construction, dry flood proofing solutions are used in rural areas of South Sudan. They are commonly materialized in the form of dikes employing sandbags, steel sheets, mud, or recycled materials such as tires (see Figure 4). However, the efficiency of such dikes is linked to the construction quality and materials employed, and concerns are raised regarding the extraction of the materials from the surrounding areas and the effects that this activity might have on the erosion of the soil. As a result, ACTED reports that local communities in South Sudan prefer the construction of elevated platforms (either individually or at the community level) to build dikes or dry flood proofing solutions [10].

Figure 4. Different systems for dike construction in South Sudan: (a) retaining wall with used tires [10], (b) steel sheets, (c) mud dike, and (d) sand bags.

Regarding active systems, buoyant approaches are the most commonly employed solution for housing and shelters in areas prone to floods. Also named amphibious foundations, buoyant constructions are a cost-effective, resident-friendly alternative to permanent static elevation for housing in areas where rising flood waters are not accompanied by high flow speeds [19]. They allow houses and shelters to remain close to the ground under normal conditions but rise as much as necessary when flooding occurs. Unlike passive approaches as stilts or dikes that disrupt the day-to-day living of the resident owners, buoyant foundations diffuse risk and increase a community's resilience, working with flood water rather than trying to fight it, as schematically shown in Figure 5.

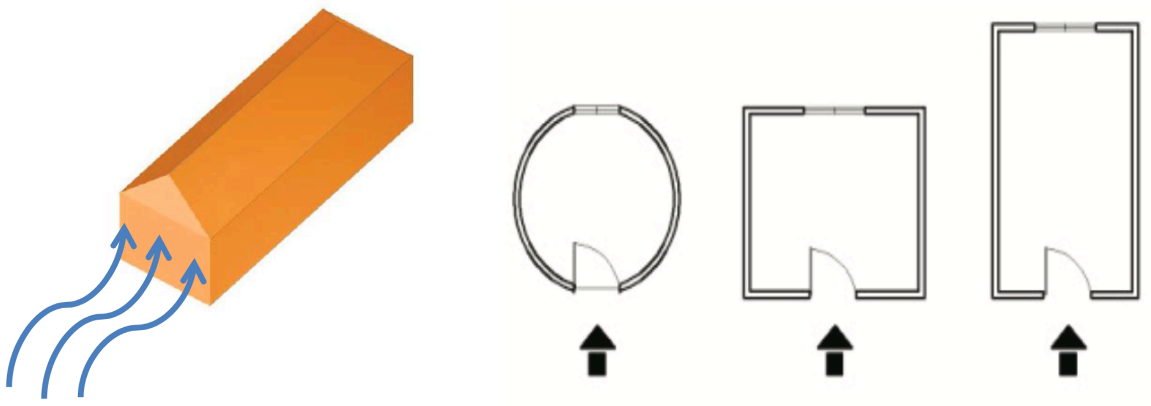
Figure 5. Schematic representation of the working mechanism of buoyant solutions during dry and flood seasons [20].

The amphibious retrofit concept comprises three basic components: a buoyancy system that displaces water and provides flotation during the flood, a vertical guidance system to prevent any horizontal movement of the house as it rises and falls, and a structural subframe that connects these new components to the existing house. A buoyant foundation can accommodate varying levels of water and is less susceptible to hurricane and wind damage compared to statically elevated homes [20,21]. The use of local materials and local construction practices are encouraged when implementing the system, allowing location-specific site issues to be addressed and accommodated. Buoyant foundation technology is easily adaptable and replicable by local markets, thus both supporting the local economy and promoting community resilience and independence [20]. This approach can be employed as a design strategy from the very initial conception of the shelter, as well as a retrofitting solution for existing structures in flood-prone areas. The applicability of buoyant solutions has been validated in several places around the globe, such as Jamaica [22], Vietnam [23], Bangladesh [24], India [25], and Canada [12].

(a) (b)

Figure 6. Examples of buoyant houses: (a) Louisiana USA [19], (b) Mekong Delta Vietnam [26].

When individual retrofits are not possible to be executed to cope with upcoming floods, previous investigations have validated the suitability of community flood shelters [27]. These infrastructures are large constructions that during the dry season are employed as schools, community centers, medical centers, or offices of charity organizations. However, during the flood season when many people face the need to leave their housing, community flood shelters are designed to host large groups of displaced individuals. Usually, community flood shelters are built on higher lands to avoid the increased water level and adapted with special facilities to provide comfort to their occupants during long time periods. However, some disadvantages of this solution have been found through consultation with communities [27], such as lack of privacy, insufficient food supply, dirty surroundings, low capacity, or lack of cooking facilities. In order to provide community flood shelters with enough resistance against high water levels, special detailing is required for the foundations so as to guarantee structural stability and long-term durability. Besides, for larger constructions, the orientation of the shelter should be that the shorter side of the house shall be facing to face the direction of the flooding as shown in Figure 7(a), and openings should be placed in line with each other on opposite walls creating a flow path for water as illustrated in Figure 7(b) [5].



(a) (b)

Figure 7. Placement of buildings for flood resilience: (a) house orientations [5], and (b) placement of openings [5].

On the other hand, Marques [8] proposed a generic methodology for developing flood resilient construction, basing the main design flow around four fundamental criteria to flood-resilient housing: site selection, design, foundations, and materials. Although the methodology does not address site-specific issues, it might be employed in different areas with different constructions cultures. The aforementioned methodology comprises six steps: (1) determination of flood factors, such as source, wave directions, or elevation, (2) identification of flood zone, (3) implementation of site selection requirements, (4) implementation of design requirements and recommendations, (5) implementation of foundation requirements and recommendations, and (6) implementation of material requirements and recommendations. In order to achieve adequate flood resilience levels, the steps of this methodology should be in accordance with well-defined standards and guidelines for flood construction, such as the ASCE/SEI 24-14 standard [28], the FEMA 543 guidelines [29], or the IBC 2021 code [30].

3.2. STATE-OF-THE-ART: NGOs AND PRACTITIONERS

A diverse range of literature is produced in relation to flood-resilient shelter by various actors involved in providing shelter assistance, including: inter-government organizations (e.g., various United Nations agencies), non-government organizations (e.g., IFRC, Medair, Shelter-Centre), multilateral organizations (e.g., the World Bank). This diffuse body of literature is addressed here in two broad categories: 1) guidelines and standards providing general information about the forms and functions and post-disaster shelter, and 2) descriptions of examples shelter assistance – i.e., specific shelter assistance projects. To these two main groups, a third subsidiary group comprises a report that address local building practices in Bangladesh, which faces similar recurrent flooding.

3.2.1. SHELTER GUIDELINES AND STANDARDS

The body of surveyed literature featuring shelter guidelines and standards is addressed here in two sub-categories: a) generic shelter guidelines and standards, and b) flood-related shelter guidelines and standards.

3.2.1.1. GENERIC SHELTER GUIDELINES AND STANDARDS

From the subcategory of generic guidelines and standards, the concept of *transitional shelter* emerges as a fundamental principle guiding the design of shelter assistance. Transitional shelter is described as "shelter resulting from conflict and natural disasters, ranging from emergency response to durable solutions" [31], and

> *…an incremental process which supports the shelter of families affected by conflicts and disasters as they seek to maintain alternative options for recovery… Transitional shelter can be* [32]*:*
>
> 1) *Upgraded into part of a permanent house*
> 2) *Reused for another purpose*
> 3) *Relocated from a temporary site to a permanent location*
> 4) *Resold to generate income to aid with recovery, and*
> 5) *Recycled for reconstruction*

Thus, transitional shelter integrates domains of emergency humanitarian assistance and later reconstruction assistance that were traditionally addressed separately. As the prevailing paradigm of shelter assistance, the concept of transitional shelter as a process rather than a product is an important principle of designing flood-resilient shelter for South Sudan.

Within the framework of transitional shelter, numerous principles are defined in the literature to guide design of specific aspects of shelter assistance. The UN High Commissioner for Refugees (UNHCR) provides an overarching set of characteristics of adequate housing: security of tenure, availability of services, affordability, habitability, accessibility, location and cultural adequacy [33]. More specifically, the Shelter Centre [32] provides a series of 10 principles of transitional shelter: 1) assess situation, 2) involve community, 3) develop strategy, 4) reduce vulnerability, 5) agreed standards, 6) maximize choice, 7) buy time, 8) incremental process, 9) plan site, and 10) reconstruction. Some of these principles may guide the design process of options for flood-resilient shelter in South Sudan.

Alongside these broad principles, specific parameters (or characteristics) of transitional shelter can provide a basis for comparative assessment of different design options for flood-resilient shelter in

South Sudan. The literature contains various parameters, with parameters of particular relevance to the design of flood-resilient shelter in South Sudan including (in no particular order):

1) Safety
2) Lifespan
3) Size
4) Comfort
5) Privacy
6) Cost
7) Timeliness
8) Cultural appropriateness
9) Materials availability
10) Construction skills
11) Maintenance
12) Upgradability
13) Liability of implementing organization
14) Equity with hosts

Some of these specific parameters are addressed in the Humanitarian Charter and Minimum Standards in Disaster Response (a.k.a., the *Sphere Standards* [34]). In relation to shelter, the Sphere standards define a standard of 3.5-4.5m2 average shelter area per person [34], and state that the average household of five people should receive at least one 4x6m "sheet of plastic" (i.e., tarpaulin). In practice, adherence with Sphere Standards is regularly influenced by context-specific constraints and requirements.

The IFRC document Transitional Shelters – Eight Designs [35] provides good examples of shelter designs that respond to the principles and parameters circumscribing transitional shelter. While these shelter designs are not applicable to flood-resilient shelter in South Sudan, they illustrate the degree of spatial and technical simplicity that typically characterizes transitional shelter.

3.2.1.2. FLOOD AND HAZARD-SPECIFIC SHELTER GUIDELINES AND STANDARDS

The literature subcategory of flood and hazard-specific shelter guidelines and standards includes context-specific guidance relating to particular countries and flood conditions. Guidelines were reviewed that are published by organizations involved long-term reconstruction, including UN-Habitat [36], the World Bank [37], the UN Development Program [38], and Sri Lanka's National Building Research Organization [5].

In general, this group of literature provides guidance on how to make housing built using traditional construction methods more resilient to floods and other natural hazards. In particular, they provide specific guidance about issues such as site selection, material selection and construction methods to make houses safer and more resistant to effects to flooding and other disasters.

UN-Habitat [36] is intended to guide local builders and house owners, specifically in flood prone areas of Pakistan following the floods there in 2010. UNDP [38] provides similar guidance albeit addressing flood-prone areas of India. The construction techniques addressed are specifically relevant to Pakistan and are, in general, not applicable to South Sudan. Nevertheless, issues such as how to build on a plinth, solid construction of foundations to resist uplift from swollen foundations, and characteristics of good, water-resistant mud plaster are useful.

Abhas et al. [37] provide comprehensive guidance about design of housing assistance programs in post-disaster settings, specifically in relation to long-term reconstruction. The focus on enduring reconstruction limits applicability to the situation of recurrent flooding in South Sudan. Nevertheless, the document identifies seven principles of "universal design" that could inform approaches to flood-resilient shelter solutions for South Sudan, namely:

> *Principle One: Equitable Use. The design is useful and marketable to people with diverse abilities.*
>
> *Principle Two: Flexibility in Use. The design accommodates a wide range of individual preferences and abilities.*
>
> *Principle Three: Simple and Intuitive Use. Use of the design is easy to understand, regardless of the user's experience, knowledge, language skills, or current concentration level.*
>
> *Principle Four: Perceptible Information. The design communicates necessary information effectively to the user, regardless of ambient conditions or the user's sensory abilities.*
>
> *Principle Five: Tolerance for Error. The design minimizes hazards and the adverse consequences of accidental or unintended actions.*
>
> *Principle Six: Low Physical Effort. The design can be used efficiently and comfortably and with a minimum of fatigue.*
>
> *Principle Seven: Size and Space for Approach and Use. Appropriate size and space are provided for approach, reach, manipulation, and use regardless of user's body size, posture, or mobility.*

NBRO [5] provides comprehensive and thorough descriptions of technical design issues relating to disaster-resilient housing, including detailed descriptions of effects of different types of disasters, technical characteristics of a wide range of materials used in housing construction, and guidance on building design and construction techniques to mitigate effects of disasters. The document highlights effects of expansive soils which is particularly relevant given the prevalence of clay-rich *black cotton soil* in South Sudan. In relation to flooding, the document highlights *inter alia* the greater suitability of regular-shaped plans, provides guidance on raised flooring using plinths or stilts and the use of cross walls to strengthen superstructures against lateral load of flooding. While the document provides very thorough guidance for disaster resilient housing in general, the sophistication of housing designs that are addressed is of limited applicability to the situation in South Sudan.

3.2.2. EXAMPLES FLOOD-RESILIENT SHELTER ASSISTANCE

Reports describing flood response shelter assistance include project and programs undertaken in Pakistan [39–41], Bangladesh [42,43], Sudan [44], Aceh [45] and South Sudan [10]. The consistent approach to flood responsive and flood resilient housing described in all these reports is improvement, adaptation or modification of vernacular housing techniques to address specific effects of flooding.

For several of the reported projects, design or construction interventions were preceded by surveys of literature and affected communities to identify specific effects of flooding and preferences of those affected. Arup [46] includes a comprehensive literature review (with many of the same documents referenced herein). In addressing flood-resilient housing in South Sudan, Planning Alliance [10] includes the results of community consultations that identified usual responses and intervention preferences of affected communities in Warrap State, including:

1) Preference to return home after floods recede.
2) Perceptions that local infrastructure (including roads, culverts) contribute to flooding.
3) Construction of plinths on which to build housing was seen as the best response.
4) Raising floor levels (through stilts or other raised framing) was perceived as useful, though secondary to raising on plinths.
5) Scarcity of materials was viewed as a restriction on raising tukuls on stilts.
6) Wood wall and roof framing is often damaged during floods, requiring replacement.
7) Access between home and dry land during floods was a concern and the solution suggested was improved boats.
8) Food security was always a priority over shelter.

In general, the reports focus on damage and improvements to foundations and/or walls and/or roofs.

Flood damage to foundations is generally held to result from uplift of water-logged solid and is described in relation to places where masonry construction techniques predominate – i.e., Pakistan and, to a lesser extent, Bangladesh. Considering the very limited use masonry construction for housing in South Sudan, the improvement of foundations stability is perhaps of limited relevance. ADPC [42] included improved fixings of timber and bamboo posts to footings in Bangladesh using concrete and steel straps – the same general approach to improving foundations of lightweight structural framing may have relevance for flood-resilient shelter in South Sudan.

While construction of plinths was not undertaken in any of the reported projects, the utility of plinths as a flood resilience strategy is mentioned in several reports [40,42]. Methods described include monolithic plinths made solely from soil (albeit with particular clay/sand compositions) and plinths formed through initial construction of a low perimeter wall with brick or other massive materials, which is then filled with soil.

Damage to walls is consistently addressed in the reports as damage to outer surfaces of walls at lower levels. This damage may be cosmetic, such that outer wall layers such as plaster may be eroded by flood waters. In places affected by recurrent flooding (e.g. Bangladesh [42,43]), it appears that outer wall layers are sacrificial, being used to protect inner structural wall layers and replaced after seasonal flooding. Similar damage is reported in relation for flood damaged tukuls in South Sudan [10].

Descriptions of flood damage to roofs are less consistent and, perhaps, related to particular building characteristics, such as construction quality, alongside flood effects. In Bangladesh, effects of flooding increasing the weight of thatch roofs and thereby leading to structural damage is described [42]. Images of damaged roofs are included in relation to South Sudan [10], however no explanation of causes is provided.

3.2.3. LOCAL BUILDING PRACTICES IN PLACES IN RELEVANT PLACES

Among various reports of Global Shelter Cluster into local building practices a report addressing building practices in Bangladesh [47] is relevant.

Several building techniques in Bangladesh that respond to recurrent flooding are relevant to the situation in South Sudan. The construction of plinths predominates as the traditional flood resilient housing response in Bangladesh. Traditional methods for stabilizing clay-rich soils to provide more flood-resistant plaster include addition of lime, shale, chopped straw and cow urine. Different weaving techniques used for woven panels that comprise the envelope of lightweight traditional construction contrast with the more rudimentary forms of weaving observed in South Sudan, with improvements potentially providing greater adhesion for plaster and greater resistance to flood damage. In some areas, more stable wattle-and-daub construction methods have evolved that use split sections of bamboo to provide a stronger "wattle" that resists flood damage, particularly at lower levels of walls.

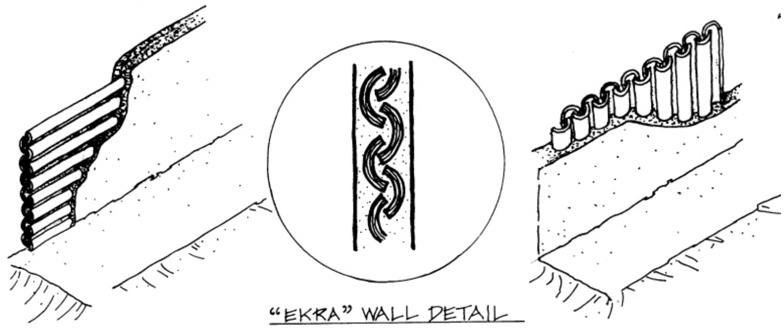


Figure 8. Strengthened wattle-and-daub construction.

In areas that are particularly flood prone, traditional demountable housing designs have evolved that enable separation of roofs from walls and separation of walls from foundations. In some cases, empty jerry cans are incorporated with roof designs to enable floating and transportation of roofs. Roof frame designs have also evolved to incorporate storage shelves that enable belongings to be stored securely above flood waters.

(a) (b)

Figure 9. Demountable buildings: (a) demountable roof, (b) jerry cans fixed to enable roof transportation

4. CONCLUSIONS

The environmental consequences due to climate change have been leading to more frequent and aggressive floods during the last few years. Due to the great damage observed in vulnerable populations, there is an imperative need for developing flood resilient solutions for housing in developing countries. Therefore, this report presents the results of a comprehensive analysis of the current literature on flood resilient solutions so as to provide the basis for further research and development on the topic. The main aim of the work presented in this report is to provide an extensive review of constructions solutions developed to deal with seasonal floods, as well as common materials and detailings to reach such an objective. Besides, this document aims at presenting a first general glance to researchers and practitioners before developing specific solutions for a given region, acknowledging that due to cultural and material constraints, general proposals are not a realistic solution in humanitarian scenarios.

The results of the work presented in this document highlight the need for developing flood resilient solutions compatible with the local vernacular construction, as well as employing local materials and tools. This is imperative so as to provide new solutions that, besides improving the response during the rain seasons, deeply fit into the culture of the communities as a common approach to building shelters and housing in general. Although it is widely acknowledged that one-fits-all proposals are not a realistic solution in humanitarian scenarios, future research should focus on generic response approaches that easily adapt to different contexts in terms of specific needs, available resources, and time scale for the operation. Without achieving such a goal, the community acceptance for new solutions might hinder a wide application of the proposed solution.

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