Chapter

Simple Housing Solution Project: (Re) Building in Critical Situations

Leandro Di Gregorio, Gustavo Guimarães, Fernando Danziger, Graziella Jannuzzi, Eduardo Qualharini, Aline Veról, Assed Haddad, Marcelo Miguez, Virgílio Cruz and Daki Bianchessi

Abstract

One of the significant challenges of recovery in critical situations (post-disaster, post-conflict, refugee settlement, among others) is the prompt and adequate housing (re)construction with scarce resources, and the affected population's involvement. The Simple Housing Solution (SHS) project consists of a proposal for a methodology for (re)construction of homes and other small buildings (schools, health clinics), using low-cost construction technologies and community labour (mutual help system). The SHS project's body of knowledge was organised in the form of a course with video lessons on YouTube and a website translated into different languages. The idea is to provide material that may help affected populations to work towards their recovery, with the support of qualified professionals (engineers and architects). The purpose of this chapter is to present the SHS Methodology and its main outputs.

Keywords: disaster recovery, post-conflict recovery, humanitarian aid, housing recovery, livelihood recovery, community recovery, reconstruction, risk management

1. Introduction

In many disasters, housing loss is the second major concern, coming soon after casualties. Simultaneously, climate change is a global reality [1] and requires adaptations of the built-up environment to adverse climate scenarios, such as hurricanes and tornadoes.

In the disaster recovery phase, rescue and relief activities are conducted relatively quickly. Nevertheless, the pace is much slower in the recovery phase, and problems drag on for years after the media have withdrawn [2].

It must be highlighted that, from an economic viewpoint, the loss of a home may represent more than family savings over a generation time. The loss of housing can also significantly increase the degree of vulnerability of those affected, with consequences for the loss of livelihoods, deteriorating physical and mental health conditions, unsafe environment for study and education, and family breakdown.

According to United Nations Development Programme (UNDP) and International Recovery Platform (IRP) [3], each house built represents an individual project, and grouping together hundreds, thousands, and even millions of homes constitutes much broader reconstruction programmes. From this perspective, it should be considered that recovery needs to be approached from two aspects: collective solutions and individual solutions that reflect each family's needs and provide specific recovery routes that take into account the peculiarities of each nucleus.

Housing provision should be understood as a process (and not merely providing a product) that should involve the people stricken by the disaster and the communities directly or indirectly affected by the situation [4]. According to UNDP and IRP [3], victims who can immediately begin their reconstruction effort will want to do so as soon as possible. Although the impact that a speedy start to recovery has on morale, those responsible for planning must ensure that the earlier vulnerabilities are not repeated. The authors also claim that in areas where immediate work is possible, there is less dependence on temporary housing, and victims feel that recovery is progressing. On the other hand, Leykin et al. [5] pinpoint three aspects that contribute directly to the resilience of a community in emergencies: preparation, leadership and collective effectiveness. Barakat [6] indicates that joint reconstruction must be carefully organised and managed, requiring managerial and technical expertise by the agencies involved in the implementation.

Concerning technical aspects, Marcial Blondet comments that in developing countries most people live in non-engineered low-rise constructions made of inferior materials, thus making them more vulnerable [7]. Considering the issues related to post-disaster reconstruction, Yi and Yang [8] mention that research efforts in developing countries in Asia and South America are far behind those in developed countries, and Africa is rarely addressed.

This chapter introduces Simple Housing Solution (SHS), a methodology designed to facilitate the reconstruction process in critical situations, and necessary for recovery with few resources (i.e., post-disaster, post-conflict, relocation from risk areas, refugee settlements). It was conceived with the philosophy of gathering basic knowledge that can help build housing units and essential collective equipment (schools, health clinics), in a joint effort (community labour system), by adopting low-cost constructive technologies. The idea is to help local governments, support agencies and, above all, vulnerable communities to better organise the process for the recovery of tens, hundreds or thousands of families with the guidance of skilled technical assistants.

2. The simple housing solution project

The SHS project started in 2009 (phase 1), and from 2017 on the project underwent improvements at the Federal University of Rio de Janeiro (UFRJ), when it was transformed into a course (phase 2). The most direct users are members of technical staff (engineers, architects, building technicians, social technicians) who have the option of using the project's content free of charge in support of their work with the affected communities. It presently relies on a website [9] and a YouTube channel [10], with about 30 video lessons. The project was one of the finalists for the 2019 Sasakawa Awards, a United Nations (UN) award in the area of disasters, with impacts on Sustainable Development Goals 1, 3, 4, 5, 6, 8, 9, 10, 11, 12, 13, 16 and 17.

2.1 Strategic SHS directives

The SHS project is based on the strategic tripod Simple Professional Design, Low-Cost Construction Technologies and Community Labour System (mutual help or joint working system), targeting the fundamental principles to a sustainable housing recovery stated by United Nations Development Programme (UNDP) and International Recovery Platform (IRP) [3]: environmental, technical, financial and socio-organisational sustainability [11].

The idea is to allow aesthetically attractive and ergonomically appropriate projects in rectangular plants that can be easily built and expanded by the community itself over time, according to needs and possibilities. Gable roofs were chosen for their simple execution and aesthetic appeal in conjunction with rustic-looking brickwork. Engineering projects were developed based on technical standards, theoretical–experimental research and laboratory analyses.

Nowadays, the technology chosen is reinforced masonry with Compacted Earth Blocks (CEBs), which allows block production using manual presses and local materials. It is also considered easy to build, and reduces greenhouse gas emissions, since the blocks are not kiln-burnt but use small ratios of 6:1 or 8:1 of soil and cement as a binder. Compared to the traditional Latin American building system (non-structural brick masonry associated with reinforced concrete structure using pillars, beams, and slabs), the proposed technology can save up to 30%. This is because it does not need wood moulds for concrete or wall cladding (except for wall façades exposed to moisture). When combined with a community labour system, the savings may reach 50% [12] of direct costs.

The interest of the vulnerable population in actively participating in the recovery work is widely documented in the literature and has been confirmed in at least three field activities (interviews):

- Reconstruction in the municipality of São José do Vale do Rio Preto, Rio de Janeiro State, Brazil, after the 2011 disaster, with 90% acceptance among the homeless [13];
- After the 2010 earthquake and Hurricane Matthew in 2016, with 100% acceptance in Don de l'Amitié, Haiti [14];
- Relocation of residents from risk areas in the municipality of Barra Mansa, Rio de Janeiro State, Brazil, with 85% acceptance among vulnerable people [15].

The adaptable enterprises of the SHS project were designed for three scenarios: 20, 50, and 120 homes, aiming to complete the work within 18 months depending on the availability of the land and resources. For the construction of more units, it is possible to replicate various 120-home developments in parallel (within the same deadline) or carry out several projects in series (adding together their deadlines).

2.2 SHS framework

The SHS methodology content has been organised into three broad thematic axes (Design, Communal Labour and Materials) representing the three strategic project directives.

The project activities were organised around the thematic axes and production of slides, spreadsheets, and video-classes, which comprise the didactic material of the SHS course and are available on the project website as they are finalised. Multidisciplinarity and interdisciplinarity are outstanding elements of the contents covered, as illustrated in **Figure 1**.

The Design macro-theme combines knowledge of architectural and engineering building designs (structural masonry, foundations, electrical, hydro sanitary, rainwater facilities) and options for the urbanisation.

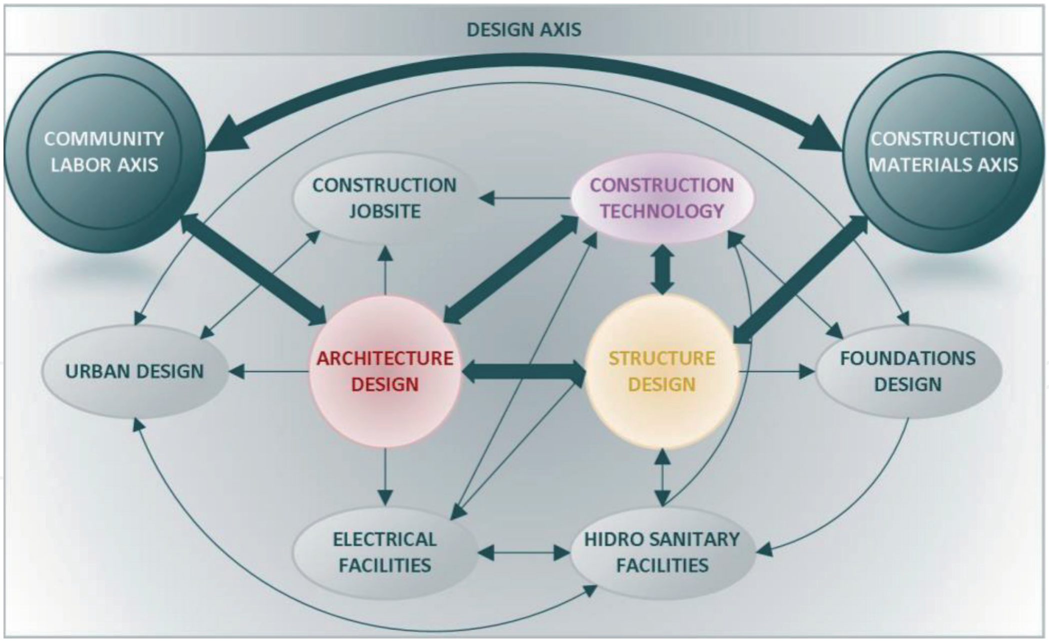


Figure 1.
Representation of multidisciplinarity and interdisciplinarity between the three axes of the SHS project. Source: [16].

WGs/Teams (Leaders)	Mission
General Coord. (1st author)	To conceive the SHS project, plan the work and manage the groups and the project as a whole.
DESIGN WG	To develop or improve basic architecture and engineering projects, compatible with the construction technology, and also develop didactic materials for the SHS course (slides and videos) on those topics.
Architecture (10th author)	To develop a basic architecture design for schools, homes, health clinics, with didactic material.
Structures (1st author)	To research and develop a basic structural design for schools, homes, health clinics, and didactic material.
Foundations (3rd and 4th authors)	To research and develop a basic foundation design for schools, homes, health clinics, with didactic material.
Electrical facilities (7th author)	To develop the preliminary design of electrical facilities for schools, homes, health clinics, with didactic material.
Plumbing facilities (6th author)	To develop a basic design for plumbing facilities (water, sewage and rain water) for schools, homes, health clinics, with didactic material.
Urban design (8th and 9th authors)	To develop basic urban planning in blocks with schools, homes, health clinics, with didactic material.
COMMUNITY LABOUR WG	Developing and or improving methods and tools to organise the project's collective labour and administration address building construction techniques, and provide didactic materials for the SHS course (slides and videos).
Construction techniques (1st author)	To address techniques and details for the construction of low buildings, with didactic material.
Construction jobsite (5th author)	To develop construction jobsite facilities for different project scenarios with didactic material.
Community labour management (1st author)	To research and develop methods and tools for community labour management, with corresponding didactic material.
Construction works admin. (1st author)	To research and develop planning and to control contents for construction work scenarios with didactic material.

WGs/Teams (Leaders)	Mission
MATERIALS WG (1st and 2nd authors)	To carry out research and experimental tests on the materials and technologies used in the project and develop didactic material on prefabrication tests, component manufacturing, and post-fabrication tests.
MEDIA WG (1st author)	To record the teams' work process and the SHS course, format documents, prepare videos, 3D animations, and develop the project's website and visual identity.
TRANSLATION WG	To translate the course material into different languages.
English*	To translate the project content into English
French*	To translate the content of the project into French.
Spanish*	To translate the content of the project into Spanish.
Creole (1st author)	To translate the content of the project into Haitian Creole.

**See Acknowledgements section.*

Table 1.
Distribution of teams and responsibilities in the SHS project.

The Community Labour macro-theme involves knowledge about community mobilisation and organisation, the construction site's organisation, the assembly of the brick factory, and the administration of construction works. Information about the construction techniques is also covered in this group.

The macro theme Materials contains the knowledge necessary to produce and test critical materials and technologies in construction technology. Currently, the project efforts are focused on structural CEB reinforced masonry technology. Furthermore, studies began on applying structural masonry with recycled aggregate concrete blocks, especially where construction and demolition waste are readily available.

The 2nd phase of the SHS project was organised in five multidisciplinary working groups (WGs), involving 16 teams, with the distribution of responsibilities according to **Table 1** and the participation of five UFRJ units: Polytechnic School, Coppe, Faculty of Architecture and Urbanism, School of Communication, Faculty of Letters.

3. Results and discussion

3.1 Design options

3.1.1 Architecture

To meet different scenarios depending on each eventual situation, three families of home projects were considered based on easy module design, environmentally friendly materials, and urgency in construction:

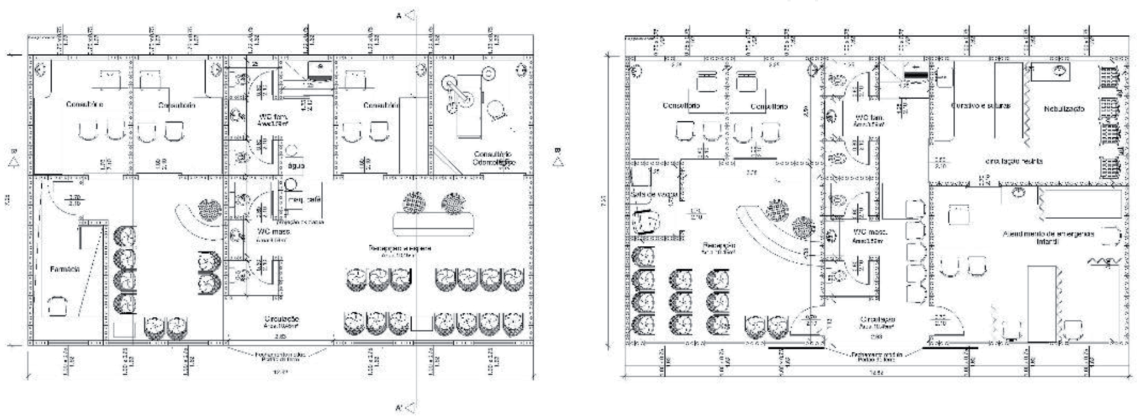
- Family A: Residential modules with minimal sizes, intended for conventional homes in the short/medium term, for light horizontal loads and simplified module design. It does not apply to events such as earthquakes and hurricanes.

- Family B: Residential modules comply with the *Minha Casa Minha Vida* Programme (Brazilian programme providing affordable housing for low-income populations). They are designed for conventional situations (light horizontal loads) of continuous permanence. These projects have an approximately 10% larger built-up area compared to Family A and provide greater essential comfort and expansion.

- Family C: This single storey residential module 2C was designed for moderate horizontal loads, aiming at the context of earthquakes and hurricanes. This family module will not be included in this chapter, but is addressed in detail in [11, 17, 18]. Liquefaction mitigation was analysed using earthquake drains as a low-cost solution [19].

Based on light horizontal load scenarios, two health clinic modules, six school modules, and four home modules were planned based on the SHS project directives:

- Health modules (**Figure 2**; see Video 1, Video 1 can be viewed at https://youtu.be/PGMr2FmfTxQ): Each health module was designed to function as an autonomous unit with an area of about 92m^2, but in conjunction with other units. The community can annex different health modules and thus build adaptable health clinics:
    - ○ Module 1 contains patients' reception/waiting room area, pharmacy, washrooms, three medical offices and a dental surgery;
    - ○ Module 2 has reception, restrooms, child emergency care area, area for dressings, sutures, and nebulisation, as well as two medical offices.
- School modules (**Figure 3**; see Video 2, Video 2 can be viewed at https://youtu.be/Q5gZLSOF4lE): Each school module was designed to function as an autonomous unit around 92m^2 in area, but in conjunction with other units so that the community can combine school modules and thus build adaptable schools:
    - ○ Module 1 contains restrooms and two classrooms with capacity for 42 students;
    - ○ A library, restrooms, kitchen, cafeteria and teachers' room can be found in Module 2;
    - ○ Module 3 has restrooms, administration and computer areas;
    - ○ A nursery area, bathrooms with shower and nursery can be found in Module 4;



(a) (b)

Figure 2.
(a) Health module 1. (b) Health module 2. Source: [20].

   - Module 5 contains an auditorium with 42-seating capacity, restrooms, kitchen and covered patio area for recreation;

   - Restrooms and two classrooms for group work, each with a capacity for 32 students, can be found in Module 6.

- Residential modules (**Figure 4**; see Videos 3–6, Video 3 can be viewed at https://youtu.be/BgfojYVUTT0; Video 4 can be viewed at https://youtu.be/51-diapmCwE; Video 5 can be viewed at https://youtu.be/ZMXMYRVCb_4; Video 6 can be viewed at https://youtu.be/od1HyQq8vC0): It begins with an elementary module (embryo 1, with living room, kitchen, bathroom, laundry area) with the capacity to temporarily house a family of four or less in projects with substantial cost restrictions. Embryo 2 has a horizontal expansion of embryo 1

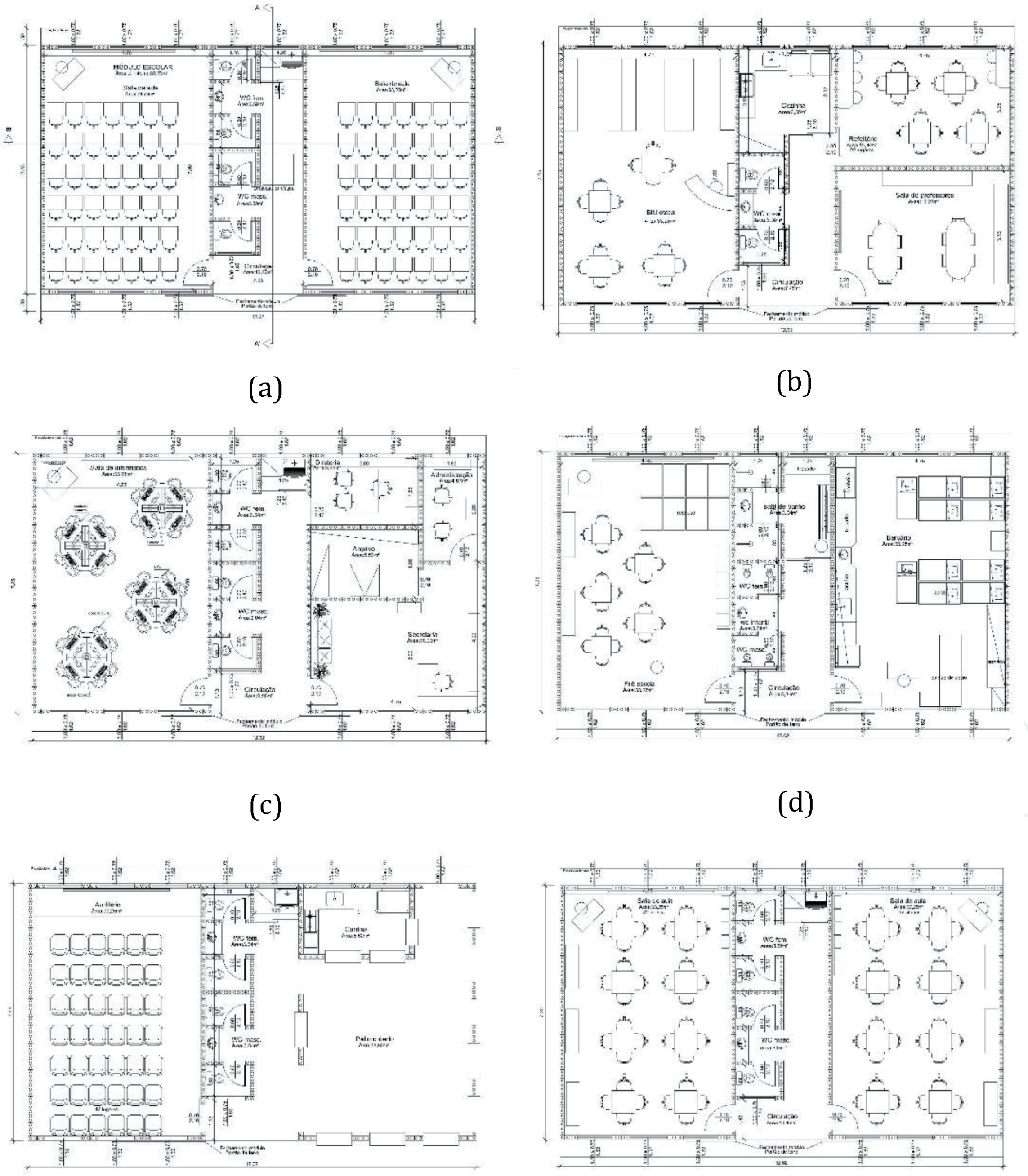

(a) (b) (c) (d) (e) (f)

Figure 3.
(a) to (f) School modules 1 to 6, respectively. Source: [20].

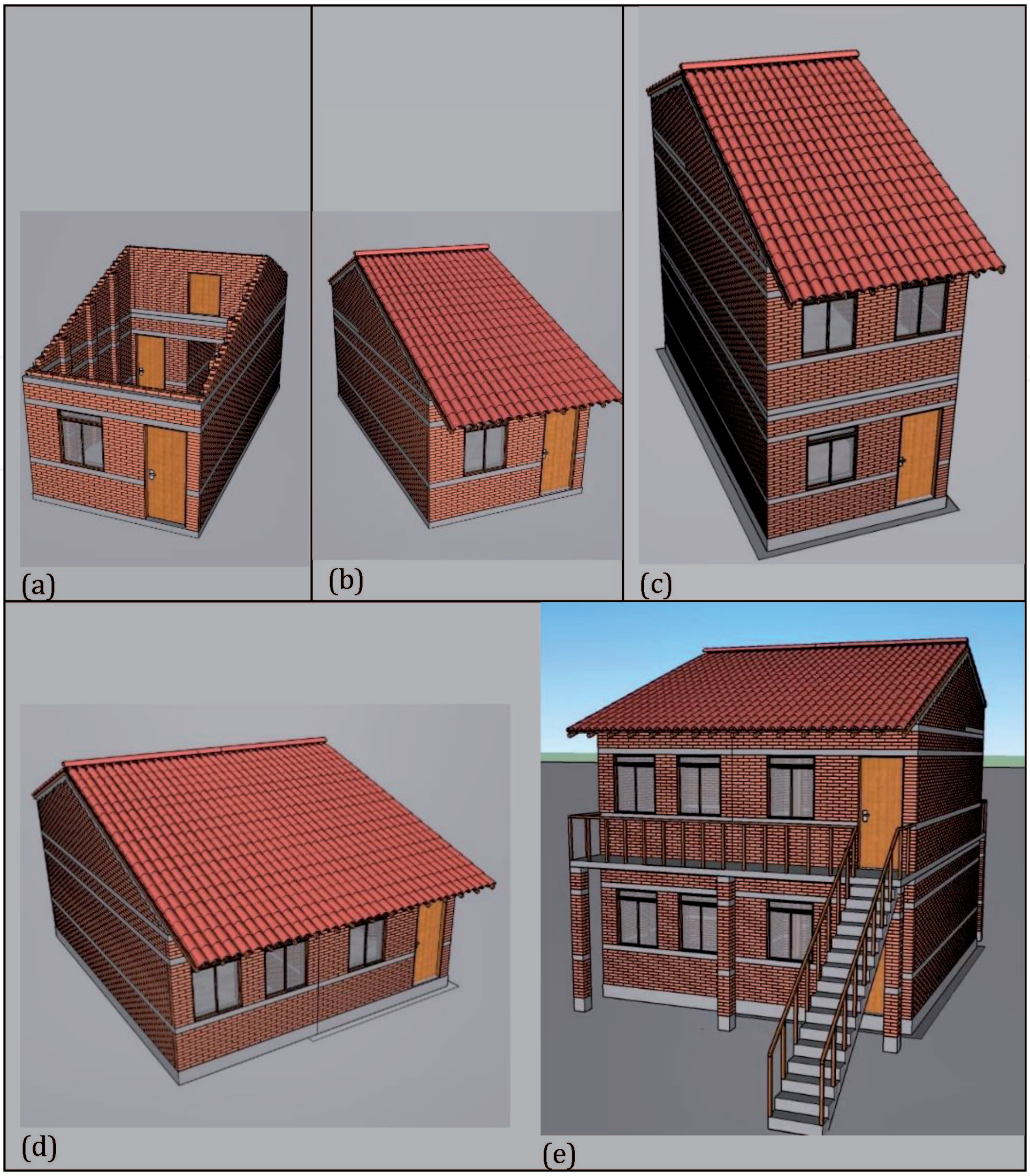


Figure 4.
Expanding possibilities for residential modules from embryo 1. (a) Internal view of embryo 1 (see Video 3). (b) External view of embryo 1. (c) Vertical expansion of embryo 1 to embryo 3 (see Video 4). (d) Lateral expansion of embryo 1 to embryo 2 (see Video 5). (e) Vertical enlargement of embryo 2 to embryo 4 (see Video 6). Source: [21].

(plus two bedrooms) and can house a family of six or less. Embryo 3 consists of vertical expansion of embryo 2 (embryo 1 plus two bedrooms) in situations with space restrictions on the building site. Embryo 4 consists of a vertical enlargement of embryo 2, in order to accommodate two families.

3.1.2 Structures and foundations

The structural system option adopted in the SHS project is that of structural masonry, noting that so far priority has been given to the reinforced masonry technology with two-hole compacted earth blocks (CEBs). However, studies on the application of masonry with concrete blocks have also been carried out [22], with favourable results.

In the CEB reinforced masonry system, the blocks are laid with mortar, and consist of masonry panels with a structural function, and stiffeners where necessary (especially at the side of doorways and windows). At points predetermined by the designer, reinforcements are positioned in the holes of the blocks (and embedded in the foundations), which are subsequently filled with fluid concrete (grout). As part of the CEB masonry system, there are reinforced concrete bond beams on five levels (below and above window openings and doorways, at the slab level, at the gable half-height, and perimeter of the roof gables). The structural system also has a set of frames that integrate the masonry with the purlins using the stiffener connections at the level of the contour concrete bond beams) (**Figure 5**).

Considering that there are still no technical standards that address the design of structural masonry in CEB, the calculations were based on the adaptation of the former British standard BS 5628–2 (2005), which was considered adequate due to its history of success and addresses different materials. The minimum strength of the brick established by the NBR 8491 (2012) standard is 2 MPa and several tests were carried out on the materials used in the project to determine the parameters used in the structural calculation, as mentioned in Section 3.3. Wind calculations were performed according to NBR 6123 (1988). The combination of loads was made according to NBR 8681 (2004).

Strip footings (with light reinforcement) under the walls were used as foundations. In order to reduce the excavation and backfilling costs, the footing installation was designed for a very shallow depth, 0.40 m. An allowable stress of only 50 kN/m^2 was adopted to allow the same foundation dimensions in almost all possible soil types. Even with this conservative value, soil investigations are recommended. Since almost all types of soil investigations require some sort of costly equipment and trained crew, the DPL (dynamic probe light, ISSMFE, 1989, ISO 22476-2: 2005) was chosen for this purpose. The DPL is a simple test that employs light inexpensive equipment, and can be carried out by local personnel with simple training. The test consists of continuous driving a standard cone (with a nominal base area of 10 cm^2) into the soil using a 10 kg hammer with a 500 mm drop height (**Figure 6**). The number of blows to drive the cone 10 cm (N_{10}) must be logged. In general, the test can reach a maximum depth of 8 m [24]. The N_{10} value can be used as an indirect measurement of soil resistance. However, there are no reliable correlations between N_{10} and allowable stresses for shallow footings, as in the case of the standard penetration test (SPT). Therefore, the use of minimum values of N_{10} = 6 to a depth of 5 m was a conservative suggestion in the present application.

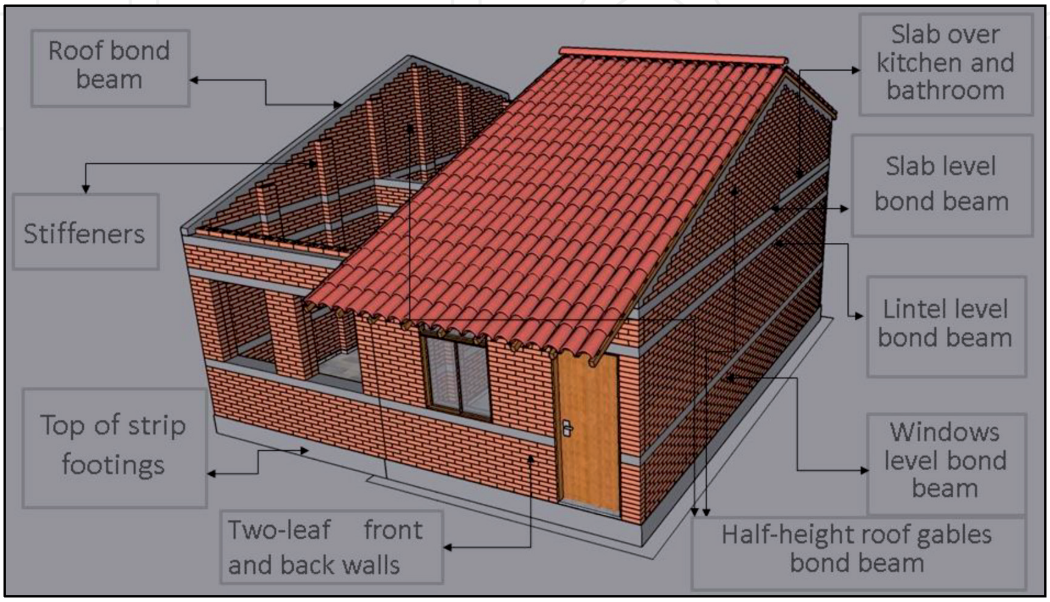
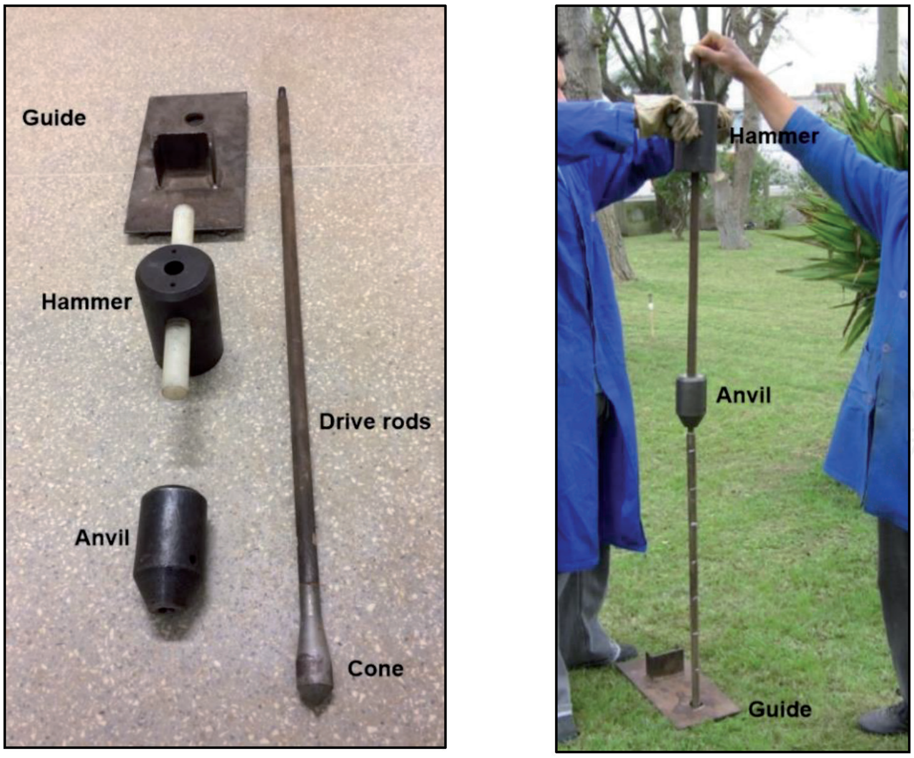


Figure 5.
Elements of the structural system of the embryo 2. Source: [23].



(a) (b)

Figure 6.
DPL (a) equipment; (b) testing. Source: [25].

3.1.3 Building facilities

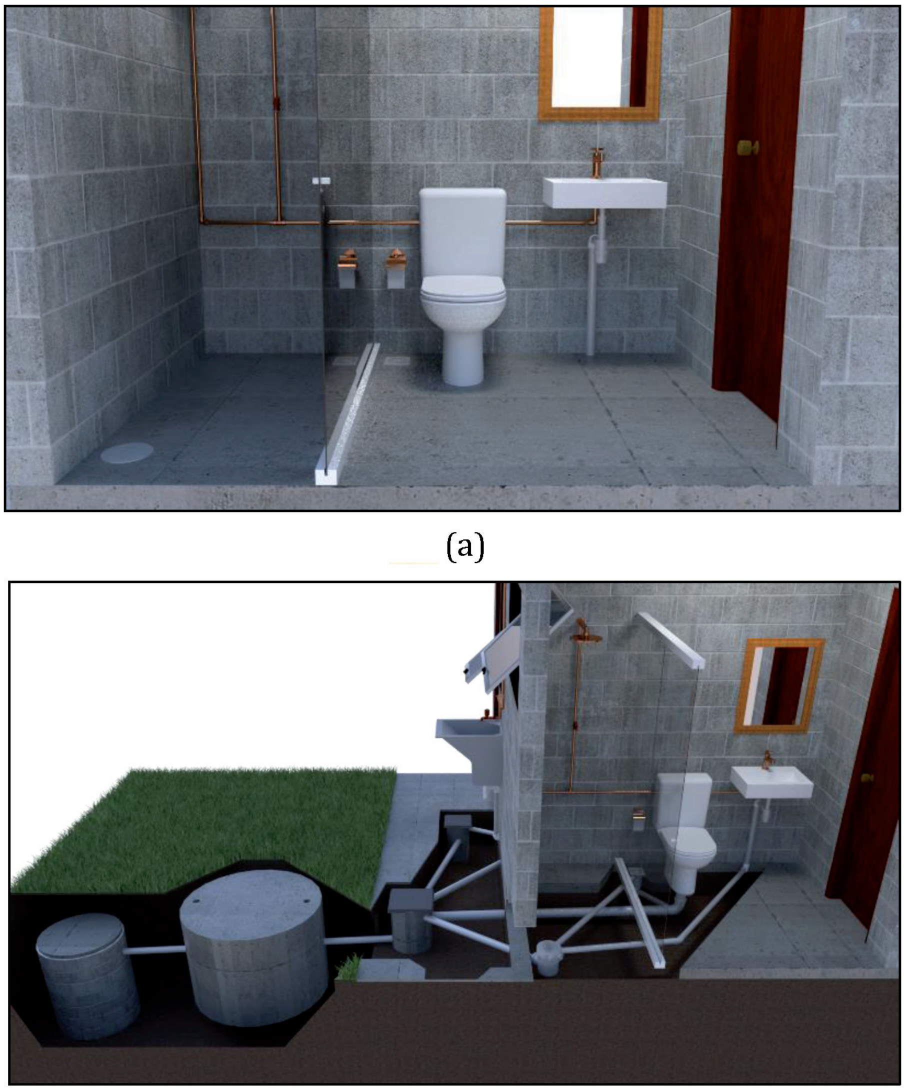
The electrical facilities for the SHS project buildings were designed according to standard NBR 5410 for two types of power supply: two-phase and three-phase lines with a 220v phase-to-phase voltage, with grounded neutral and electrical apparatus.

When the brick holes are not grouted, they act as conduits for the wires, which do not require pipes on route to the points of use (switches and sockets). When the pipes are embedded in concrete holes, they must be inserted into preferably flexible conduits. The light fixtures are attached to the roof rafters. The switchboard is located outside the masonry (overlapping), close to the bathroom, in order to reduce wire consumption in the kitchen and electric shower circuits.

The apparent vertical plumbing system was designed for easy maintenance and to avoid holes in the walls, since they have a structural function. The water supply and distribution system were designed considering the use of apparent piping, preferably PVC, considering the cost–benefit ratio of this material and its easy procurement (**Figure 7a**). The system is directly connected to the public water supply network and does not require a pumping system. It was proposed to use a 1000-litre elevated water tank for smaller prototypes, and two 1000-litre units for the larger.

A standard internal solution was proposed for the water distribution in standpipes, branches and sub-branches to enable future expansion. This solution is identical in embryos 1, 2, and 4 and slightly different in embryo 3, because of its particular architecture. In this case, the pipe is built into the bedroom walls.

The sewage system was designed in PVC, using ceiling cladding to separate the pipes from the domestic environment. The waste and vent pipes were placed in the corners of the rooms and inbuilt with plaster. Considering that vulnerable communities would not have a formal sewage system, the proposed solution would be



(a)

(b)

Figure 7.
(a) Internal distribution system - bathroom with apparent pipes. (b) a waste collection system in the bathroom and laundry area with a primary treatment system. Source: [26].

an individual sewage treatment system using a combined septic tank and sinkhole (**Figure 7b**).

Concerning the rainwater drainage systems, a simplified solution was proposed. The rainwater flows from the roof to catch basins and then to the public storm water system, whenever applicable. As an alternative, a rainwater harvesting system can be installed using rain barrels (**Figure 8**). In this case, it is necessary to install gutters, roof drains and downspouts connected with a rain diverter to the rain barrel. These barrels would accumulate the rainwater, reserving it for less exciting use, such as washing floors.

3.1.4 Urban design

Different typologies of the urban subdivision were conceived for a pilot project considering at least 100 homes in embryo 2, including the necessary community facilities (schools, health centres and public squares) to serve the expected population. For each 100-home model, simple replication logic was applied to extend the project in case of more significant needs, for example, when an entire neighbourhood has to be built (**Figure 9**).

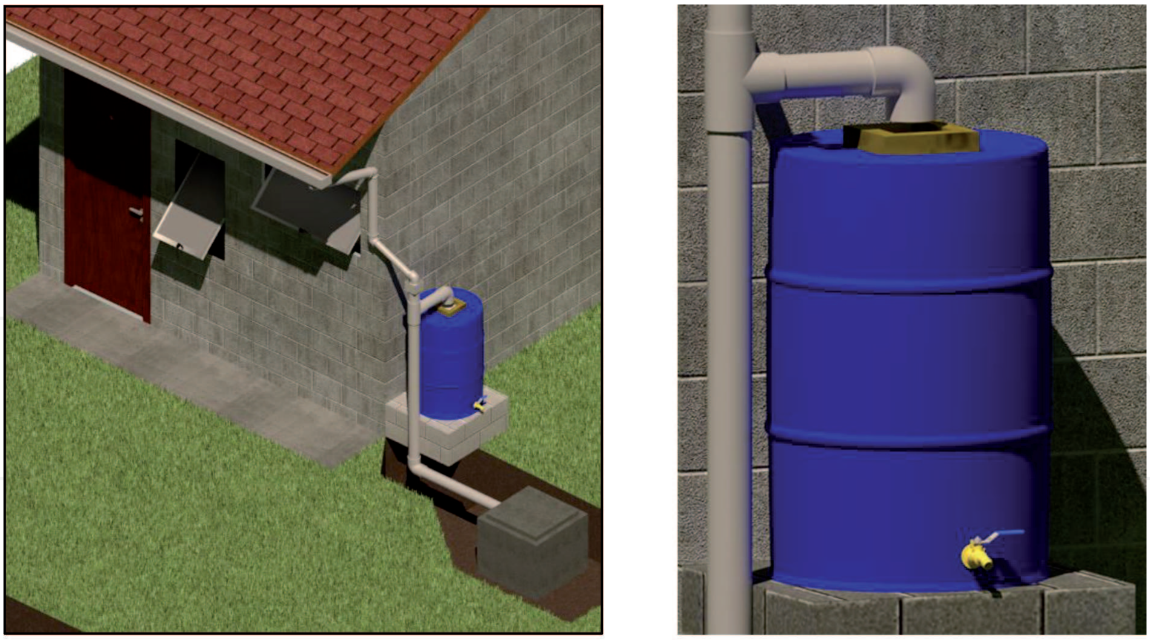

(a)
(b)

Figure 8.
(a) Rainwater harvesting system; (b) rain barrel. Source: [26].

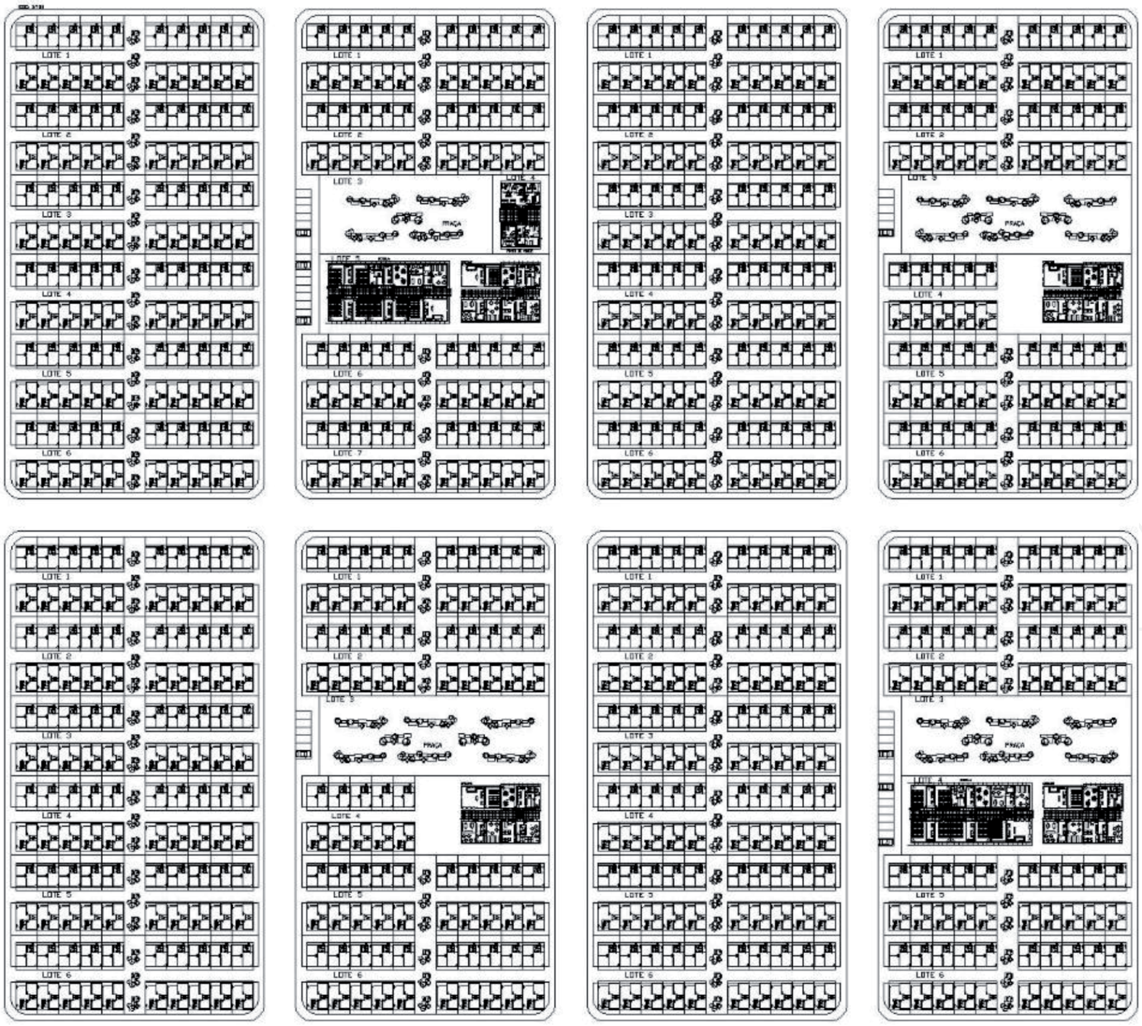


Figure 9.
Strategy for replicating residential and hybrid blocks (containing community facilities designed for the local population), based on typology 2 ("village" type). Source: [27].

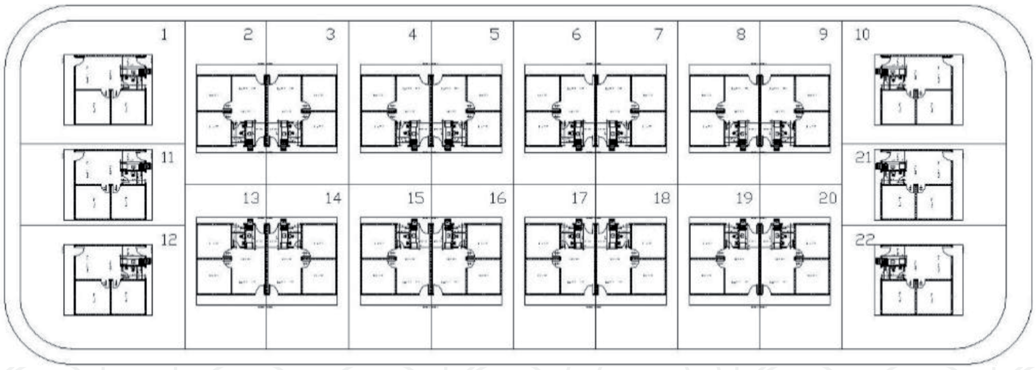


Figure 10.
Lot distribution on a typical residential block with semi-detached houses. Source: [27].

Figure 11.
Single lot with multiple houses in the "village" typology. Source: [27].

The following urban typologies were considered in detail (mainly facing a smooth topography):

- Typology 1 (**Figure 10**): Grid – single-family home lots distributed in rectangular blocks shaped by orthogonal streets. Two different designs were used: the first considered mirror image semi-detached houses to save urban space and define smaller lots; the second considered traditional homes centred in the lot area.
- Typology 2 (**Figure 11**): Grid – "village" type consists of multiple houses in a shared lot (each owner has a fraction of the site, in a condominium arrangement), with more significant block areas.
- Typology 3: Radial – based on a single-centre model that can be replicated with several interconnected centres – used for uneven and hilly ground and not fully detailed in the project's first phase.

Both typologies 1 and 2, which are suggested for flat or sloping ground, were detailed in the design process. Typology 3, more adaptable to rugged and uneven ground, was only developed conceptually, considering the inherent implementation problems, lacking the facility for community labour system.

Table 2 shows a comparative analysis for a hypothetical case of 200 houses, showing that the "village" setup saves urban space, with a considerably higher number of dwellings per area, thus consuming less area per home throughout the development.

Detailed comparative analyses were made for the proposed urban typologies planned to relocate the population from flood-prone areas, in the municipalities of

Typology	Description	Area per house (m^2)
Individual lots, with standard centred houses	193 lots +6 schools +4 nurseries +2 local health centres +1 public square	286
Individual lots with semi-detached houses	Idem	233
Shared lots of "village" type	200 lots +6 schools +4 nurseries +2 local health centres +1 public square	156

Table 2.
Average urban area implementation per house for different developing typologies.

Mesquita [28] and Barra Mansa [15], in Rio de Janeiro State, Brazil. These analyses confirmed that urban typology 2 (community villages) is more efficient both in terms of space and implementation cost of the development.

3.2 Community labour system

3.2.1 Building construction technique

Building construction techniques consider all the construction processes related to the technologies adopted (currently, CEB reinforced masonry).

The CEB reinforced masonry process starts with batter boards, excavation, and execution of the shallow foundations. The foundations are usually concrete stripped footings, with at least 20 MPa of compressive strength. They should be built over a thin layer of lean concrete. It is crucial to pay attention to the mix grade, especially the water/cement ratio, which should be as low as possible. The vertical rebar of the grouted holes in the CEB masonry has to be implanted in the footings (see Video 3).

See the "Structure and foundations" section to build the CEB masonry, the grouted holes, bond beams, and portico system. It should be mentioned that the electrical conduits could be installed inside the CEB masonry holes. Simultaneously, plumbing installations must be external (see the section of "Building facilities", which also provides rainwater and sewer drainage).

The places most exposed to water or moisture (masonry base, bathrooms – namely showers, kitchen, laundry room, service area, and base of external walls) should be waterproofed. An acrylic texture coat or any waterproofing resin should be applied to the outside of house façades. CEB masonry should be preserved as much as possible against direct action of moisture. It must be stressed that CEB masonry may become less durable when exposed to water in the long term. A layer of compacted gravel around 3–5 cm in thickness should be inserted between the compacted soil and the ground level concrete slab to protect against moisture.

The type of roof tile adopted will depend on the gable roof, so if the choice is a ceramic/clay tile, either a higher slope or extra wooden structure will be required.

3.2.2 Construction jobsite

The construction jobsite was designed to: reduce the area, increase efficiency and safety of the construction process, reduce travel distances of both construction material and people, and also to avoid any barrier to plant movement.

A couple of layouts of jobsites were designed for different developments (construction of 20, 50, and 120 homes). All arrangements at the jobsite include elements related to production (carpentry and concrete/mortar mixer), production support (warehouse, cement and lime deposits, and concrete aggregate storage bays), technical and administrative support (security cabin, site office, medical facility) and living areas (canteen, changing rooms and restrooms).

A layout design was also considered, including a CEB brick production plant and a control technological laboratory for the materials used in CEB masonry technology. This layout was designed to create a housing development with smaller areas [29].

For example, in the case of a 120-home development (embryo 2A), the average cost of the CEB masonry plant per home is above half the average cost per house of a 20-home development. Therefore, in the case of building a CEB plant, a 120-home development proves to be far more efficient.

3.2.3 Administration of community labour and construction works

In addition to technical knowledge and people management skills, the organisation and administration of developments using community labour address challenging issues and require a certain degree of sensitivity, especially considering the vulnerability of the population affected.

This section is adapted from [30] and includes processes and activities for the organisation and management of community labour, namely: viability and security of the project, types of management, creation of an association for the people affected, technical assistance, setting up committees and teams, organising tasks, legal and financing issues, providing designs and planning construction works, distribution and receipt of finished houses, creation of the social factory, registration of families and workers, task force training, and issues related to withdrawals, warnings, and exclusions.

It is worth explaining that two types of administration must work in parallel, having a high degree of interdependence between them: the administration of community labour and administration of the construction works. While the former will take care of the community, the latter will address construction planning (time, cost and resources), control of time, cost, and stock control.

Construction planning is aligned to the "lean construction" philosophy, adapted from the "lean production" concepts. Therefore, a maximum of 120 households per project has to be respected (if there are more households, then several projects should be implemented in parallel or series).

Dynamic tools (spreadsheets) for construction planning and control were developed, based on an algorithm designed for SHS [31]. These tools allow users to configure their development's specific input parameters, such as the number of homes, embryo types, number of workers per household, expected task force efficiency, payroll and automatically obtain the development's essential planning and control structure.

Five task groups were created with different duties: Foundations, Masonry, Roof, Facilities and Finishes, each with a manager in charge (see Video 7, Video 7 can be viewed at https://youtu.be/Hg0TezfNWqc). Volunteer workers would comprise these groups (in more significant numbers, from the affected community and its relationship network, preferably skilled) and contract workers (in smaller numbers, to meet qualified professionals' specific needs).

First of all, it is necessary to have time dedicated to training the task force, preferably using some hands-on activity to familiarise them with construction of the buildings. It is recommended that this "preparation time" of the project should take at least two months and no longer than six months. During this time, various measures can be taken, such as design adaptation, legal measures to start the project, and implementing the jobsite.

Another fundamental point addressed in the SHS project is how to calculate the hours for recording each household's working hours (hour bank) and the criteria adopted to prioritise the delivery of the homes. To support these tasks, a time control tool was also developed, which provides the structure for recording the hours worked (with the possible transfer between households) and an automatic list for prioritising the distribution of homes at different stages of the development.

3.3 Construction materials

Two deposits of unsaturated tropical soil (Soil 1 and Soil 2), located in Macaé, Rio de Janeiro, Brazil, were investigated, and a geotechnical characterisation was carried out in the laboratory.

Soil samples were prepared and tested according to international standards. Soil preparation, grain-size distribution, specific gravity and Atterberg limits were obtained according to ISO 23909 (2008), ISO 17892-4 (2016), ISO 17892-3 (2015), and ISO 17892-12 (2018) respectively [32, 33]. An empirical test was also carried out to check soil shrinkage during the natural drying process.

CEBs were manufactured using a mechanical hand press, from a mixture of 50% Soil 1 and 50% Soil 2, in volume. The final mixes used cement as a binder with 2% of lime and water content (CEB water absorption) next to 20% (**Figure 12a**-**c**). It

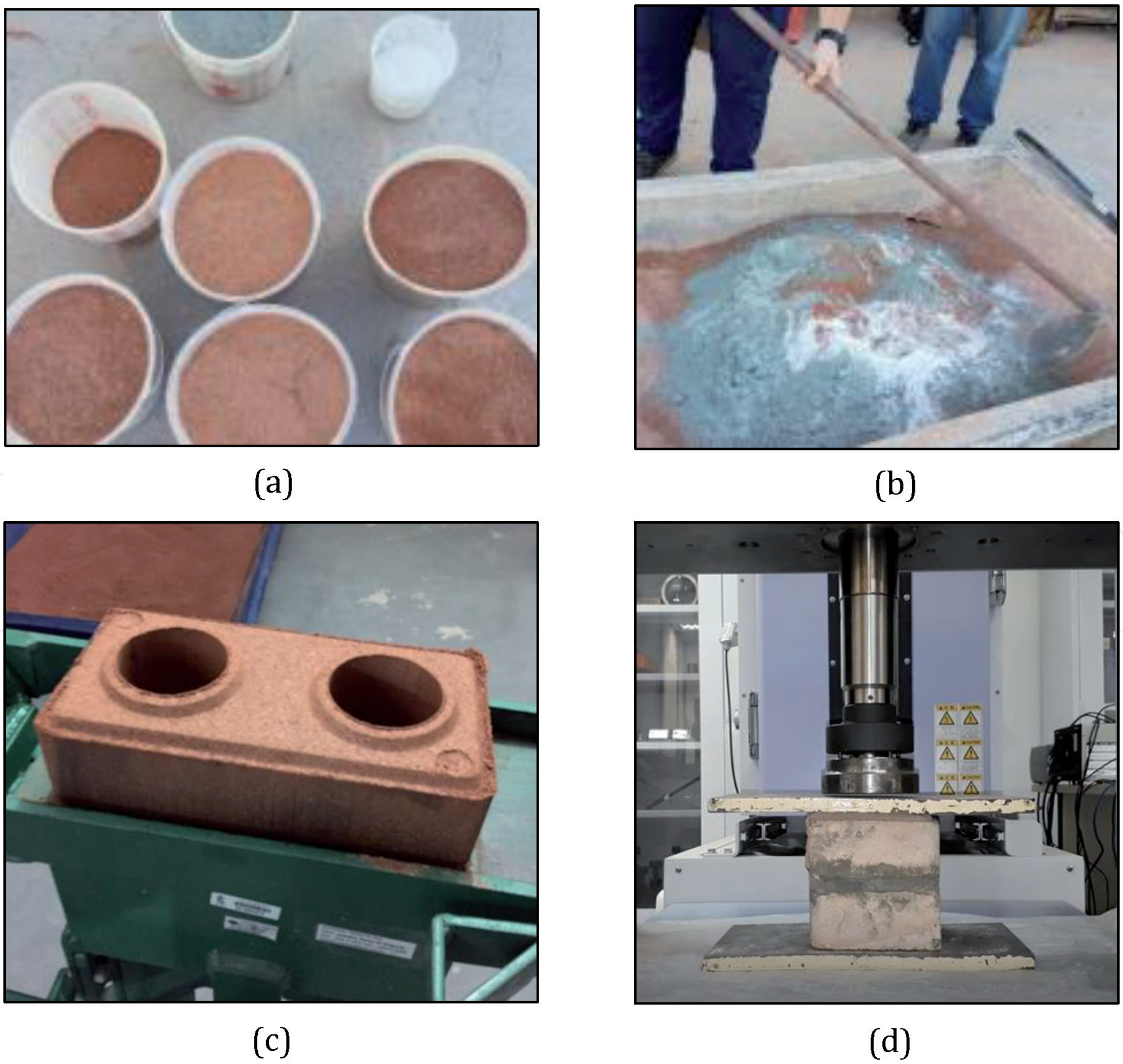

(a) (b)
(c) (d)

Figure 12.
(a) Soil preparation, (b) Material's mixture, (c) CEB's production (d) CEB compressive strength test. Source: [34].

should be pointed out that water content could significantly vary within different types of soils. CEB water absorption and compressive strength were verified according to NBR 8492 (2012) (**Figure 12d**) [32, 33, 35]. Tests on wallets equivalent to two grouted columns per metre and fully grouted columns were carried out to obtain mechanical properties and wallet-block efficiency [33, 17]. The main results and extensive discussion can be found at [11].

Horizontal load capacity tests were used to obtain inputs for computational models used to investigate the proposed residential model under seismic conditions, performed according to NBR 15421 (2006). The test consisted of applying a horizontal load on a wallet one metre in length (equivalent to 4 blocks per tier), a clear width of 10.5 cm, and a height one metre (equivalent to the elevation of 13 tiers of blocks and a joist at the top). All the specimens had their blocks laid manually in a ~ 1 cm thick mortar joint. The reinforced bond beams had the same width as the blocks and reflected the panel's upper confinement. Vertically, the wall had its lateral holes reinforced and grouted. In addition to these, two more intermediate holes were symmetrically reinforced and grouted, representing panels with two reinforced holes per metre. The load was manually increased and applied by a hydraulic jack placed in the middle of the joist section. The displacements were measured using linear variable differential transformer (LVDT). A load cell was used to monitor the load. Displacement and load were acquired at the same time using a data acquisition system [11, 17].

4. Conclusion

Housing recovery in situations where urgent construction is necessary but resources are scarce (such as post-disasters, post-conflicts, refugee settlements, and so on) is a challenging task requiring technical skills, management, and focus on the affected population. The Simple Housing Solution (SHS) methodology was developed to contribute to empowering governments, support agencies and, above all, vulnerable communities. It is presented in the course format and based on the tripod Simple Professional Design, Low-Cost Construction Technologies, and Community Labour System.

The first class on the SHS course was held in October 2018 for an audience of 30 people: 15 Haitians living in Brazil and intending to return to their country to participate in the reconstruction process; three members of the non-governmental organisation (NGO) Engineers Without Borders Brazil; three members of the NGO Teto; three community members affected by a relocation process near UFRJ; two employees from the municipality of Niterói (Rio de Janeiro State, Brazil); two employees from the municipality of São Lourenço (Minas Gerais State, Brazil); one graduate student from the Federal University of Santa Catarina, and one refugee from the conflict in Syria. Since then, two other reduced versions of the course were offered in 2019: one at the Federal Institute of Maranhão, Brazil, on the manufacture of soil-cement bricks, during the 5th Maranhão Symposium on Civil Engineering, and another at the Federal University of Pará, Brazil, on SHS Methodology, during the 3rd Brazilian Congress on Disaster Risk Reduction.

It should be noted that the educational material developed under the SHS project is intended to be a starting point and should be evaluated and adapted to each implementation reality by the local technical assistance team. However, the material provided can greatly expedite reconstruction work, mostly because of the project's simplicity, pre-planned work, accessible construction technology, and tools developed to administer the community labour and construction works.

Aiming to expand the project's scope, it currently seeks to improve the embryo 2C, the SHS model for multi-risk situations involving more aggressive horizontal loads in reinforced masonry technology in CEB [11]. For this reason, new tests are being proposed for SHS project phase 3, when it is necessary to perform cyclic tests in porticos and dynamic tests in full scale on shake tables.

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Author details

Leandro Di Gregorio[1]*, Gustavo Guimarães[2], Fernando Danziger[3],
Graziella Jannuzzi[4], Eduardo Qualharini[1], Aline Veról[5], Assed Haddad[6],
Marcelo Miguez[7], Virgílio Cruz[4] and Daki Bianchessi[8]

1 Environmental Engineering Program/Urban Engineering Program/ Polytechnic School, Federal University of Rio de Janeiro, Rio de Janeiro, Brazil

2 Civil Engineering Department, Federal University of Rio de Janeiro, Macaé, Brazil

3 Civil Engineering Program Alberto Luiz Coimbra Institute of Graduate Studies and Engineering Research - Coppe, Federal University of Rio de Janeiro, Rio de Janeiro, Brazil

4 Polytechnic School, Federal University of Rio de Janeiro, Rio de Janeiro, Brazil

5 Graduate Program in Architecture – PROARQ, Urbanism and Architecture Faculty, Federal University of Rio de Janeiro, Rio de Janeiro, Brazil

6 Environmental Engineering Program/Polytechnic School, Federal University of Rio de Janeiro, Rio de Janeiro, Brazil

7 Environmental Engineering Program/Polytechnic School, Civil Engineering Program Alberto Luiz Coimbra Institute of Graduate Studies and Engineering Research – Coppe, Federal University of Rio de Janeiro, Rio de Janeiro, Brazil

8 Infanti Engenharia, Nova Iguaçu, Brazil

*Address all correspondence to: leandro.torres@poli.ufrj.br

References

[1] IPCC, 2018: Summary for Policymakers. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. In Press.

[2] Nakagawa Y., Shaw R. Social Capital: A Missing Link to Disaster Recovery. In: International Journal of Mass Emergencies and Disasters, 2004, v. 22, n. 1, pp. 5-34. Available from: http://ijmed.org/articles/235/download/ [Accessed: 2020-10-24].

[3] United Nations Development Programme, International Recovery Platform. Guidance Note Recovery: Shelter. [Internet]. 2010. Available from: https://www.undrr.org/publication/guidance-note-recovery-shelter [Accessed: 2020-10-24].

[4] International Federation of Red Cross, Red Crescent Societies. Owner-Driven Housing Reconstruction. Geneva [Internet]. 2010. Available from: https://www.sheltercluster.org/sites/default/files/docs/Owner-Driven%20Housing%20Reconstruction%20Guidelines.pdf [Accessed: 2020-10-24].

[5] Leykin D., Lahad M., Cohen R., Goldberg A., Aharonson-Daniel L. The dynamics of community resilience between routine and emergency situations. International Journal of Disaster Risk Reduction, 2016, v.15, 125-131. DOI: 10.1016/j.ijdrr.2016.01.008

[6] Barakat S. Housing Reconstruction After Conflict and Disaster. Humanitarian Practice Network [Internet]. 2003. Available from: https://odihpn.org/resources/housing-reconstruction-after-conflict-and-disaster/ [Accessed: 2020-10-24].

[7] Le Maoult A., Politopoulos I., Atanasiu G.M., Casarotti C., Pavese A., Dorka U., Nguyen V. T., Marazzi F., Molina Ruiz F. J., Pegon P. EFAST project (Design Study of a European Facility for Advanced Seismic Testing). 1st-year EFAST annual report. Commissariat à l'Énergie Atomique, Technical University "Gheorghe Asachi" of Iasi, European Centre for Training and Research in Earthquake Engineering, University of Kassel, European Union, 2010.

[8] Yi H., Yang, J. Research Trends of Post Disaster Reconstruction: The Past and The Future. Habitat International, 2014, v.42, 21-29. DOI: 10.1016/j.habitatint.2013.10.005

[9] SHS Solução Habitacional Simples [Internet]. 2018a. Available from: https://www.shs.poli.ufrj.br/ [Accessed: 2020-10-24].

[10] SHS Solução Habitacional Simples – Aulas em Português BR [Internet]. 2018b. Available from: https://www.youtube.com/watch?v=QEY0ZaOz8AY&list=PL515-FzRssVNGAsgIrQNgU3LCld3DGtrY [Accessed: 2020-10-24].

[11] Di Gregorio L., Guimarães G., Tenório M., Lima D., Haddad A., Danziger F., Jannuzzi G., Santos S., Lima S. (2020). The Potential of CEB Reinforced Masonry Technology for (Re)construction in the Context of

Disasters. Materials. 13(17). 10.3390/ma13173861.

[12] Santos R.L.R. Orçamento, planejamento e gerenciamento de obras de residências de baixo custo em regime de mutirão: caso de estudo do Projeto Solução Habitacional Simples [undergraduate monograph]. Rio de Janeiro: Federal University; 2019.

[13] Di Gregorio L.T. Proposta de ferramentas para gestão da recuperação habitacional pós-desastre no Brasil com foco na população atingida [doctoral thesis]. Niterói: Federal Fluminense University; 2013.

[14] Alerte J. Proposta de (re)construção de casas populares em regime de mutirão como alternativa ao déficit habitacional do Haiti [undergraduate monograph]. Rio de Janeiro: Federal University of Rio de Janeiro; 2017.

[15] Silva J. M. Análise de viabilidade da metodologia "Solução Habitacional Simples" para realocação de áreas de risco de inundações do município de Barra Mansa/RJ [undergraduate monograph]. Rio de Janeiro: Federal University of Rio de Janeiro; 2019.

[16] Di Gregorio L.T. Projeto SHS: (Re) construção em situações críticas com tecnologias de baixo custo. In: IV Simpósio Maranhense de Engenharia Civil – SIMEC; 12-16 agosto 2019; São Luís, Brazil. Oral Presentation.

[17] Tenório, M.C.U. Análise da viabilidade técnica da alvenaria estrutural em tijolos de solo-cimento para situações com cargas sísmicas: práticas construtivas e análise estrutural do projeto de solução habitacional simples [Undergraduate monograph]. Rio de Janeiro: Federal University of Rio de Janeiro; 2019.

[18] Gonçalves, F.S. Aspectos construtivos para residências de baixo custo sob a ação de ventos fortes [undergraduate monograph]. Rio de Janeiro: Federal University of Rio de Janeiro; 2018.

[19] Benvenuti Junior M. P. Análise de Sistemas de Fundações Visando à Mitigação de Danos Causados por Sismos: Caso de Estudo Projeto Solução Habitacional Simples (SHS) [Undergraduate monograph]. Rio de Janeiro: Federal University of Rio de Janeiro; 2020.

[20] Bianchessi D. I. P., Di Gregorio L. T. Projetos de arquitetura. In: Di Gregorio L. T. org. Projeto SHS – Material Didático. 2012.

[21] Bianchessi D. I. P., Di Gregorio L. T. Projetos de arquitetura. In: Di Gregorio L. T. org. Projeto SHS – Material Didático. 2018.

[22] Freitas J.P.B. Aspectos estruturais, construtivos e orçamentários para construção de casa popular em blocos de concreto em situações críticas [Undergraduate monograph]. Rio de Janeiro: Federal University of Rio de Janeiro; 2019.

[23] Di Gregorio L. T. Projetos de estruturas. In: Di Gregorio L. T. org. Projeto SHS – Material Didático. 2019.

[24] ISSMFE - International Society for Soil Mechanics and Foundation Engineering. Report of the ISSMFE - Technical Committee on Penetration Testing of Soils - TC 16. Reference to Test Procedures CPT-SPT-DP-WST. Suécia: Swedish Geotechnical Institute Information, n. 7, 1989.

[25] FURG Universidade Federal do Rio Grande. Pictures of DPL Equipment and Testing Source. 2017.

[26] Veról A. P., Di Gregorio L. T. Projetos de instalações hidrosanitárias e

águas pluviais. In: Di Gregorio L. T. org. Projeto SHS – Material Didático. 2018.

[27] Miguez M. G., Cruz V. N. R., Di Gregorio L. T. Projetos de urbanização. In: Di Gregorio L. T. org. Projeto SHS – Material Didático. 2018.

[28] Duarte C.C.R. Urbanização de interesse social: um estudo da organização do espaço urbano para realocação da população em área de risco de inundação no município de Mesquita (RJ) [undergraduate monograph]. Rio de Janeiro: Federal University of Rio de Janeiro; 2018.

[29] Resende D.M. Projeto e estudo da logística do canteiro de obras com uma fábrica de tijolos de solo-cimento integrada: uma análise prática do projeto solução habitacional simples [undergraduate monograph] Rio de Janeiro: Federal University of Rio de Janeiro; 2019.

[30] Di Gregorio L. T. Manual para fabricação de tijolos de solo-cimento. Rio de Janeiro. 2012.

[31] Di Gregorio L. T. Algorithm for Communitary Labour Construction System. 2018.

[32] Sousa J.F. Fabricação e análise de tijolos de solo-cimento. Undergraduate Monograph in Civil Engineering, Federal University of Rio de Janeiro, Rio de Janeiro, 2018.

[33] Lima, D.A.S.M.F. Avaliação do tijolo modular de solo-cimento fabricado em prensa manual como material para construção de baixo custo com mão de obra comunitária. Undergraduate Monograph in Civil Engineering, Federal University of Rio de Janeiro, Rio de Janeiro, September 2018.

[34] Di Gregorio L. T., Guimarães G. V. M. Component testing for soil-cement masonry. In: Di Gregorio L. T. org. Projeto SHS – Material Didático. 2018.

[35] Lobo, G.M. Efeito da umidade de fabricação na resistência à compressão de tijolos solo-cimento. Undergraduate Monograph in Civil Engineering, Federal University of Rio de Janeiro, Rio de Janeiro, 2019.