Chapter 14
From Resilient and Regenerative Materials to a Resilient and Regenerative Built Environment

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Abstract Urban environmental degradation and disasters are leading to a paradigm shift towards implementing regenerative and resilient concepts on all scales. The interrelationship between microscopic and macroscopic elements of the built environment must be considered from pre-design through to building handover to avoid future disasters and environmental degradation in urban areas. This paper aims to identify synergies between the resilient and regenerative design activities needed on all scales and dimensions. The developed conceptual framework represents the context in which the study is conducted. Cooperation strategies on different scales are required to mitigate the climate crisis by reflecting the dimension of increasing energy consumption requirements from materials to the urban built environment in cities. The methods used to answer the research questions are data analysis from literature and trend comparisons at local, regional and global levels. New approaches and interrelationships were found by testing hypotheses in different design traditions and socio-economic situations. Research findings clearly showed that a new concept has to be created as a cooperative system of discrete disconnected parts in scale-jumping design based on the synergies from regenerative and resilience design and practice. This paper concludes with new concept design principles that need to be implemented in daily life to support the creation of resilient and regenerative solutions for the built environment.

Keywords Disaster · Resilience · Regenerative · Design and scale jumping

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14.1 Introduction

Many manmade products together with natural materials are used to create resilient and regenerative architecture. Some products are better suited than others as resilient and regenerative building solutions. New strategies in the construction sector are calling for a paradigm shift, a new approach, innovative ideas and continual evolution of culture in relationship with resilient and regenerative materials in architecture.

In this chapter, ‘materials’ are analysed in the context of use for creating micro and macroscopic architectural elements. Many natural materials have been used to create buildings. Some authors call for new uses of green materials as innovative and creative solutions. Green materials such as hemp can be a good alternative to more toxic petrochemical-based materials (Attia, 2016).

However, as pointed out by Ness and Xing (2017: 575), ‘for the construction sector to transition to a circular economy, systemic innovation throughout the value chain is necessary’. Design plays the main role in this transition towards resilient and regenerative products with economic and environmental benefits that consist in cost control and reduced negative environmental impact. Good building design is critical to closing resource loops (Thormark, 2001). The construction sector has been identified as one of the three high-potential sectors for seizing the economic and environmental benefits (SystemIQ et al., 2017).

Changes in microscopic and macroscopic scale transformations are needed to shift the paradigm towards resilient and regenerative architecture. Creating and using adequate construction materials that adapt to the environment is the best way to build resiliently and regeneratively. The paradigm shift is possible by building a microscopic-scale environment, by taking an innovative biomimetic approach for increasing immunity, identifying and avoiding deterioration and recovering damaged materials. This innovative approach towards smart materials will produce a synergy of values placed on the built environment by construction materials and will provide a much higher level of confidence and reliability in the performance of our architecture and built environments.

Buildings, together with the construction industry, account for more global final energy use and energy-related carbon dioxide (CO_2) emissions than all other industries when material manufacturing and building construction products are included. The built environment consists of manmade building (residential commercial, industrial etc.) and infrastructures such as transportation, communications, streets, energy, water systems, parks and landscaping.

Building end-of-life management is critical to enable material recovery and to prepare for reintegration into the value chain (Nordby, 2009).

Recovering cracks at multiple scales, determined by time, cyclic loading damage and identifying and immunizing against physical damage, will be followed by automated diagnosis and automated healing from chemical damages. Building modelling, tailoring and up-scaling address a diverse range of applications.

The main beneficiaries of resilient materials will be industry, the construction supply chain and those responsible for the provision, management and maintenance of the world's built environment. Working with resilient materials across the supply chain and engaging with complementary initiatives will develop a suite of real-life regenerative architecture. Creating a network in this field will further enhance the diversity and reach of intelligent, self-healing construction materials that will allow for further exploitation of established relationships with the international community to maximize the impact and thereby generate new initiatives in a wide range of related bacteria, chemistry, agents, prophylactics, tailoring and modelling. Nano-structures, polymer composites, sensors, instrumentation and advanced manufacturing will combine to create new biogenic building materials.

New technologies make it possible to revise traditional construction materials and techniques to give new life to renewable and regenerative building materials such as straw, clay and wood-based solutions. EcoCocon is a regenerative example of a prefabricated wall panel composed of locally sourced straw insulation, Forest Stewardship Council (FSC)-certified wood-stud structure and wood fibreboard exterior cladding (see Fig. 14.1). The interior panel surface is ready for interior clay plaster. The Passive House Institute in Germany and the Cradle-to-Cradle Product Innovation Institute have both certified the product meaning that it is suitable for highly energy-efficient construction and is certified to be recyclable. What cannot be recycled can be composted at the end of the building life because it is composed of 98% renewable materials (Kierulf, 2020).

This paper focuses on proactive and reactive dimensions of resilience and regeneration at all scales and the relationships between them. The concepts of resilience and regenerative design use social, spatial and environmental strategies to increase

Fig. 14.1 EcoCocon wall panel, an example of a regenerative building product (Kierulf, 2020)

a community's abilities to avoid and reflect on disasters, as well as mitigating climate crisis and decreasing energy consumption. In Fig. 14.2 below, a framework is presented that explains the context in which research is conducted (systems, approaches, construction value chain for building life cycle, causes-effects of disasters and environmental degradation, interdependence of concepts from actions in all scales) together with development criteria at all scales, systems and interrelations between individual actions.

The following questions were raised when identifying the context and global trends on mitigating climate crisis and deflecting increasing energy consumption:

- Do interrelations between resilient and regenerative designs at different scales (from materials to the built environment in the city) and dimensions improve living in harmony with nature?
- How changed approach of design and construction can produce resilient and regenerative elements for a built environment that are socially, spatially and environmentally healthy and safe to human and natural systems at both the microscopic and macroscopic scales?

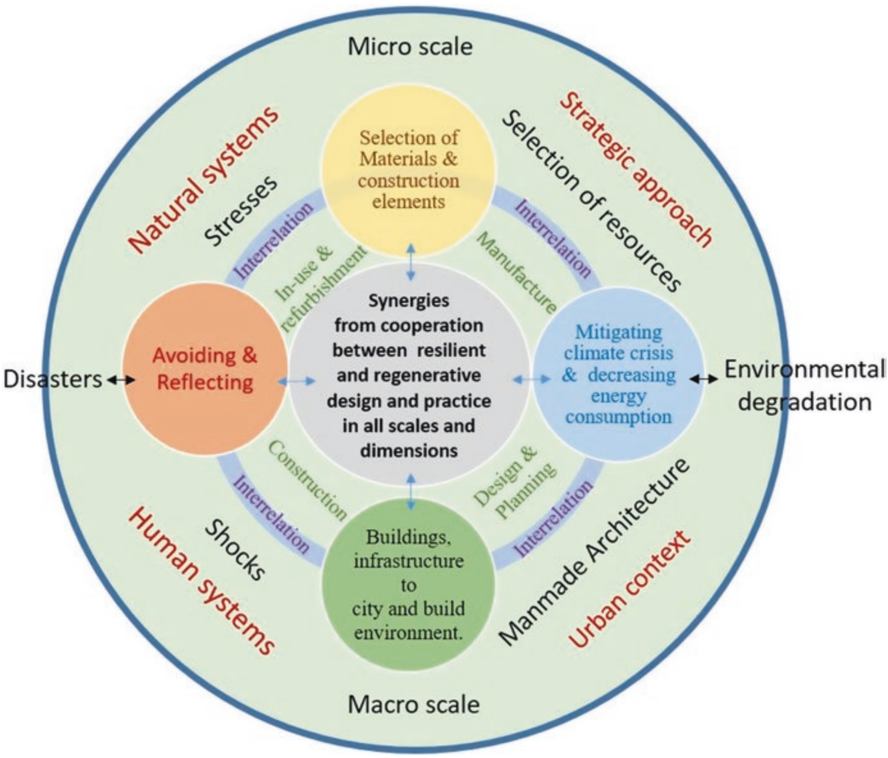

Fig. 14.2 The conceptual framework represents the scope of the conducted study

14.2 Methods

The research is empirical and employs a confirmatory approach that builds on the relational view as a primary theoretical foundation. Analytical and comparative methodologies are used to identify trends and linkages between concepts.

Synergies from resilient and regenerative design and practice are identified and presented in the conceptual framework as seen in Fig. 14.2. The conceptual framework represents the content in which the study is conducted. It is based on the accepted theories and experiences. The conceptual framework is designed as an analytical tool for providing solutions for environmental degradation and disasters.

This tool is used to identify conceptual distinctions, organize actions and accepted ideas to serve as the guiding research principles in a way that is easy to remember and apply.

The background of the study is conducted and presented within the context of the points outlined in Fig. 14.2. The illustration uses a systems-thinking approach showing the relationships between human and natural systems to approaches for regenerative design and practice within its overall context. The construction value chain for the whole building lifecycle is prevalent from the microscopic scale at the top to the macroscopic scale at the bottom. The causes and effects of disasters and environmental degradation are visible at the left and right periphery of the circular model. All actions within the built environment interact at all scales with each other and are interdependent.

Analysing the conceptual framework in the figure above, it is easy to identify synergies. A system thinking approach during the decision-making process avoids shocks and stresses, and maximizing interactions from design interrelationships on different scales. Building projects are assessed based on the lifecycle benefits that resilient time scales and regenerative design phases bring to the built environment. All elements of the built environment from the microscopic to macroscopic scales, and other systems, integrate and adopt new flexible concepts to unforeseen challenges in the future.

This conceptual framework is designed based on literature analyses keeping in mind that both concepts (regenerative and resilient design and practice) are reflections on disasters and environmental degradation at all scales, from microscopic through to macroscopic scales.

Disasters are affected by stresses in natural systems and shocks from human systems. Environmental degradation is affected by the selection of resources as a strategic approach and manmade architecture in the urban context. Energy consumption must be decreased as an answer to environmental degradation together with other measures on both the microscopic and macroscopic scales to avoid and reflect on disasters and to mitigate the effects of the climate crisis.

The interrelations between different actions are represented as coloured circles in Fig. 14.2. All scales of resilient and regenerative design and practice produce synergies that come from cooperation on social, spatial and temporal dimensions.

Community participation during the design process is vital at all scales from resilient and regenerative materials to a resilient and regenerative built environment during the entire life cycle planning process, from the implementation to the post-occupancy stage.

Conceptual interdependence from the cooperation between actions at all scales increases its added value to the construction chain for the building lifecycle.

As presented in Fig. 14.2, avoiding and reflecting disasters with resilient design depends on the selection of materials and construction elements during the design process, while the building is in use, and during the refurbishment phase at a microscopic scale. Buildings, urban infrastructure and the built environment during the construction phase are dependent upon macroscopic scale considerations.

It is necessary to take actions that are dependent on a selection of materials and construction elements during manufacturing on a microscopic scale, while on a macroscopic scale, it is dependent on design and planning scales. Mitigating the climate cri-sis and decreasing energy consumption as reflected by environmental degradation with regenerative design must also be considered.

Cooperation between resilient and regenerative design and practice at all scales and dimensions have shown that synergies can be produced, which will result in a resilient and regenerative environment. The identified interdependence and interrelation-ships of all actions are essential for the success of the projects for the entire building life cycle from the initial concept to the eventual reuse, disassembly or renewal of the building in another form.

14.2.1 Comparative Case Studies

The Iranian-born architect and founder of the CalEarth Institute, Nadir Kahlili, developed his concept of SuperAdobe in the 1980s initially as a system to empower the poor and refugees to be able to build their own homes using an abundant natural material: earth (Cal-Earth Inc. 2016a). The system is based upon filling long, tubular-shaped plastic or fabric bags with a mixture comprised of 10% cement and 90% locally available materials: earth (e.g. sand and/or clay), natural fibrous materials (e.g. sticks, straw and/or manure) and water (Morishita, Haj Ismail, & Cetin, 2017).

The importance of involving traditionally excluded stakeholders in an integrated design process can be seen when comparing the application of the ‘SuperAdobe Bags’ from CalEarth (Cal-Earth Inc. 2016d) in the Konbit Shelter project that rebuilt the village of Cormiers in Haiti after the 2010 earthquake, and the application of the same technology for the UNHCR Baniniajar Refugee Camp in Khuzestan, Iran (Morishita et al., 2017).

The Konbit Shelter Project built a community centre and two single-family homes over four years from 2010 to 2014 (Konbit Shelter, 2013a, 2013b, 2013c). In addition, Konbit Shelter also built one family home in 2017 built from bamboo. Konbit Shelter continues active in the maintenance of the buildings in collaboration with the local community. The team was comprised of a team from American creative communities, a farming organization and the village of Cormiers, Haiti. The team also built up the community because the buildings reflected the local vernacular, incorporated local art and community values and taught the community to work together by building the structures together. Even though the community centre and the SuperAdobe houses incorporated local art and community values, they do not reflect the local vernacular architecture. It thus trained the local population not only about how to build using the SuperAdobe technique, but they earned a good wage while building, and the structures are a source of pride for the community (Curry, 2013). Caledonia Curry, the project initiator, not only ensured that the milestones were celebrated but also brought the team together daily for a shared meal after each day's hard work cementing the bond between the members from both the United States and Haiti (Curry 2017).

CalEarth built the Baninajar Refugee Camp for UNHCR as a shelter project for Marshland Arabs in 1995 (Cal-Earth Inc. , 2016b). Fifteen SuperAdobe houses were built together with the inhabitants of the refugee camp. Because a detailed needs analysis was not conducted before and during housing construction, no accommodation of gender separation in the homes, nor outdoor spaces for each home were considered. The housing did not meet the needs of the inhabitants (Stasi, 2012).

14.2.2 Living Systems in Resilient and Regenerative Architecture and Design at All Scales

A resilient and regenerative built environment at all scales needs to become a source for producing means and energy, regenerating degradation from the past, and transforming waste into health-giving resources. This requires a whole-systems approach lifestyle and development approach that takes into account both the human and non-human ecology of the built environment.

In the urban context, it is necessary to take a strategic approach and identify synergies in relationships between natural and human systems. Materials, designed elements, buildings, neighbourhoods and cities should not be considered as separated components in different scales but rather designed to become parts of larger systems that function by creating a resilient and regenerative built environment in every scale and dimension.

There are several reasons to move towards co-operations between regenerative and resilient developments.

Resilient and regenerative developments are focused on humans, as well as other systems and dimensions as a natural and united part of ecosystems. Both developments investigate how humans as a part of ecosystems are engaged to create synergies between built environment and natural systems.

Identifying the causes and effects of disasters and environmental degradation on both micro and macroscopic levels help to create new concepts to avoid and recover from disasters, mitigate climate crisis and decrease energy consumption.

A vital part of resilient and regenerative developments considers the context of each place as unique and diverse natural and architectural elements of environmental challenges and opportunities. Understanding social, spatial and environmental contexts help to identify localized responses that allow avoidance and rebounding after a disaster. Localized responses also help to mitigate climate crises and to decrease energy consumption. Every element of built environment in any scale of design has to be built to regenerate natural resources of environment. This approach aims to restore or create the capacity of avoid and reflect upon disasters, mitigate climate crisis and decrease energy consumption with system thinking to reduce human intervention.

Resilient and regenerative design is also about the relationships between architecture elements at all scales within the natural environment. Regenerative design shifts the emphasis towards systems thinking – the practice of understanding how parts influence one another within a whole (Meadows, 2002).

A systems-thinking approach is crucial to resilience and regenerative design and development. This approach supports a constantly dynamic and evolving built environment. Resilient and regenerative design and development is a positive contributor to indoor and outdoor quality of life.

Local reality (i.e. social, spatial and environmental) of a place beyond site boundaries and the human aspirations of design and development are aligned by understanding the systems-thinking approach and master pattern.

The men in the refugee camp were able to earn money for their families by selling cement blocks. They could also use the blocks they manufactured for building new homes. Because the SuperAdobe housing did not meet their needs and because the value of cement-block housing was greater, the SuperAdobe homes were eventually abandoned or destroyed by 2013 (Stasi, 2012).

This shows not only that the selected sustainable building technology is important but also the consideration of local factors such as social context for regenerative solutions. Both projects used the same SuperAdobe technique. Yet, the building team of Konbit Shelter took a very different approach to their project emphasizing joy, art and consideration of the end-users from project initiation to hand over of the successful project to the community. The Baniniajar Refugee Camp illustrates how lack of acceptance by the end-users can lead to project failure in the long term, even with the best intentions.

14.3 Results

Systems thinking and institutional promotion are necessary key strategies to maximize synergies between regenerative and resilient designs at different scales while avoiding and recovering from shocks and stresses. The importance of establishing global networks to promote collaborations between concepts is gaining increasing attention. Networks can bolster urban resilience by providing mutual support and by creating a platform for sharing knowledge, experience and to facilitate peer-to-peer learning, even in the absence of action at higher levels of government (Lu & Stead, 2013).

New concepts and approaches beginning with regenerative and resilient design at all scales and phases are needed for developing processes to creating regenerative and resilient environments. Table 14.1, illustrates jumping scales, levels and system thinking phases in regenerative and resilient design.

The same principles are followed in the resilience and regenerative design scale-jumping processes as spatial and social aspects, including all aspects of systems thinking: from materials, components, structures, buildings, cities, the built environment to human social systems and culture.

Resilient and regenerative key performance indicators at different scales and their meaning during design and construction phases are explained in the above table.

Resilient and regenerative design of materials during the executive phase is presented at a microscopic scale from 1:1 to 1:5. At this scale, building components, fixings and accessories, constructive aspects, the working of the components and how they should be constructed are also presented.

Resilient and regenerative design during the detailing phase is presented showing detailed building drawings, furniture and components at scales from 1:10 to 1:20. The need for a greater scale is obvious for smaller objects, constructions and components.

During the construction phase, resilient and regenerative design buildings are presented at scales from 1:25 to 1:75. The typical scale of 1:50 is used for building de-signs, the relationship between buildings, floor plans and other detail-specific components of architectural, MEP and structural plans.

Resilient and regenerative building design concepts are presented at scales of 1:100–1:150. The first approaches of smaller works and typologies are presented at these scales during the pre-design stage. For larger buildings, drawings and models with greater detail are considered.

Conceptual designs of resilient and regenerative neighbourhoods are presented at scales of 1:200–1:250. Building shape, volume, access, roof characteristics and the relationship amongst built and empty spaces are considered at this scale. These scales are also suitable for plans, sections and elevations of larger buildings for a comprehensive understanding of the proposal. At this scale, neighbourhood planning of resilient and regenerative neighbourhoods can even contemplate some spatial compositions and layouts.

Planning regenerative and resilient cities at scales from 1:500 to 1:1000 allows for contextual understanding without the requirement to show large regional extensions or analyses such as building heights, land use etc.

Surveys of regenerative and resilient built-environment plans are presented at scales from 1:20,000 to 1:50,000. A scale of 1:20,000 is used for urban planning and zoning maps, master plans and aerial photography surveys.

Table 14.1 Regenerative and resilient design processes and what they represent at different scales and during different phases

Regenerative and resilient	Typical scale	Scale range	Application	Phase
Materials	1:2	1:1–1:5	Items are more common in advanced project phases such as in an executive project. Building components, materials, fixings and fittings, constructive aspects, components function and how they should be built	Executive
Components	1:15	1:10–1:20	Items include detail drawings of structures, components and furniture. It is evident that a larger scale is needed in smaller objects, constructions and components	Detailing
Structures	1:50	1:25–1:75	Items include the building construction, relationships between structures, floors, flooring, specified wall coatings, interior design and detail-specific components such as plumbing, electrical or structural plans	Construction
Buildings	1:125	1:100–1:150	Included items are first designs of smaller projects and typologies. For larger buildings, drawings at greater detail and models with greater detail including structural details and interior layouts are included at this scale.	Idea
Neighbourhoods	1:225	1:200–1:250	Considerations include the building shape and volume, access, roof characteristics and the relationship between built areas and voids. This scale can be used for a broader proposal understanding for plans, sections and elevations for larger buildings. This scale can also be used for planning some neighbourhood spatial compositions and layouts	Concept
Cities	1:750	1:500–1:1000	This scale can be used for a contextual understanding of the project without the requirement to show large territorial extensions, or surveys of building heights, land use or other details	Planning
Built environment	1:20,000	1:2000–1:50,000	This scale can be used for urban planning and zoning considerations such as master plans or aerial photogrammetric surveys	Surveys

Many research surveys have compared the two concepts to clarify the relationship between regenerative and resilient solutions. Regeneration and resilience strategies reduce possibilities for conceptual misunderstandings. Furthermore, additional clarification is needed to establish how urban resilience relates to other key concepts such as adaptation, recovery and sustainability to maximize synergies and minimize trade-offs among them (Chelleri, Waters, Olazabal, & Minucci, 2015).

Regenerative design and development are based on systems thinking for creating resilient communities that harmonize between the built environment and nature. The ultimate goal of the built environment and the developmental processes related to the built environment is to support and enable 'the continual evolution of culture in relationship to the evolution of life' (Mang & Reed, 2012).

Technical strategies such as buffering, redundancy, rapid feedback, decentralization and ecosystem service integration take into consideration a site's path of least resistance. These technical strategies are effective design tools to increase resilience (Watson & Adams, 2010). The built environment is strongly affected by socioeconomic conditions and by human behaviour even though many aspects of regenerative design and resilience developments focus primarily upon the technical side. A community's long-term survival is essentially dependent upon community participation, policy and integrated design processes when considering social aspects (Mertenat & Thomas-Maret, 2012).

Implementing regenerative and resilience concepts will reduce carbon dioxide emissions more quickly than projected. Even with the growth in the green building industry, aggregate carbon dioxide emissions from buildings are projected to grow faster than any other sector through to 2030 (UNEP Buildings, 2007).

To live in harmony with nature, the regenerative conceptual design must identify the needs within the resilience design framework and synergies coming from cooperation at all scales and dimensions.

14.4 Discussion

Regenerative concepts implemented by resilient communities will create conditions for a synergy of values focusing on the built environment at all scales operating simultaneously within a project. Many authors discuss the building's role and the building's impact on the resilience and regenerative concept. However, it is not enough. Findings illustrate the need to engage all scales of design and development. Social aspects also need greater consideration for engagement in both the much smaller and larger contexts of community. Synergies must be created within each context. Using the co-operative approach includes environmental issues such as the climate crisis, energy consumption and links issues related to disasters such as the need to avoid and reflect upon disasters. The cooperative approach makes it possible to share values on all scales placed of the built environment, thus enhancing a community's resilience.

It is important to note the need to jump from one scale to another. For example, jumping from the micro-scale of material and elements to the macroscopic-scale of the neighbourhood during different phases while applying systems thinking towards resilient and regenerative design processes (see Fig. 14.3). Scale jumping and comparing relationships between elements (e.g. materials, components, structures, buildings, neighbourhood, cities and the built environment) at different scales will create possibilities to identify synergies within the design process.

The co-operative approach combining resilience, regenerative design and planning is focused on different social, spatial and environmental scales. The performance of the built environment at each scale is analysed in both the pre- and post-disaster phases, and also during the quickly developing consequences of the climate crisis.

The reviewed literature has illustrated vulnerable points: factors influencing the ability of an element in the built environment at every scale to avoid, react, recover, reflect and renew after a disastrous event. The vulnerabilities also exist for individuals or larger communities to respond to disastrous events. (Fig. 14.4).

Figure 14.3 is an illustration of the relationships of the scaled items in Table 14.1. Here the items from the microscopic to the macroscopic scales are presented with one another. Restorative and regenerative designs remain at the centre with all other aspects radiating out in a clockwise direction. The different layers from the central restorative and regenerative designs illustrate the project in all its design phases concerning the surrounding environment. The design phases begin from a small scale of 1:2 with material selection radiating out to the largest scale of the built environment at 1:20,000. The scales follow the design phases in a clockwise direction from the earliest and smallest scale to the latest and largest project scale.

The practically identified synergies and findings are different from the theoretical expectations about the resilient and regenerative built environment. Increased values result by collaborating using the resilient and regenerative approach. Integration is promoted by many theories; however, it has a less positive impact on enhancing the construction of resilient and regenerative buildings.

14.5 Conclusions

The limitations surrounding the current sustainability approach without considering regeneration and resilience are evident at all scales of the built environment.

Designing and building regenerative architecture is not enough, incorporating resilient and regenerative approaches can produce the synergies. Cooperation between both concepts is needed for applying successful design process on all scales and dimensions.

The interrelationships between measures taken on all scales and compared concepts require a cooperative approach that contributes in collaboration of concepts that will have positive impact to human and natural systems. Simultaneously, implementing stronger policies and partnerships can reduce vulnerability.

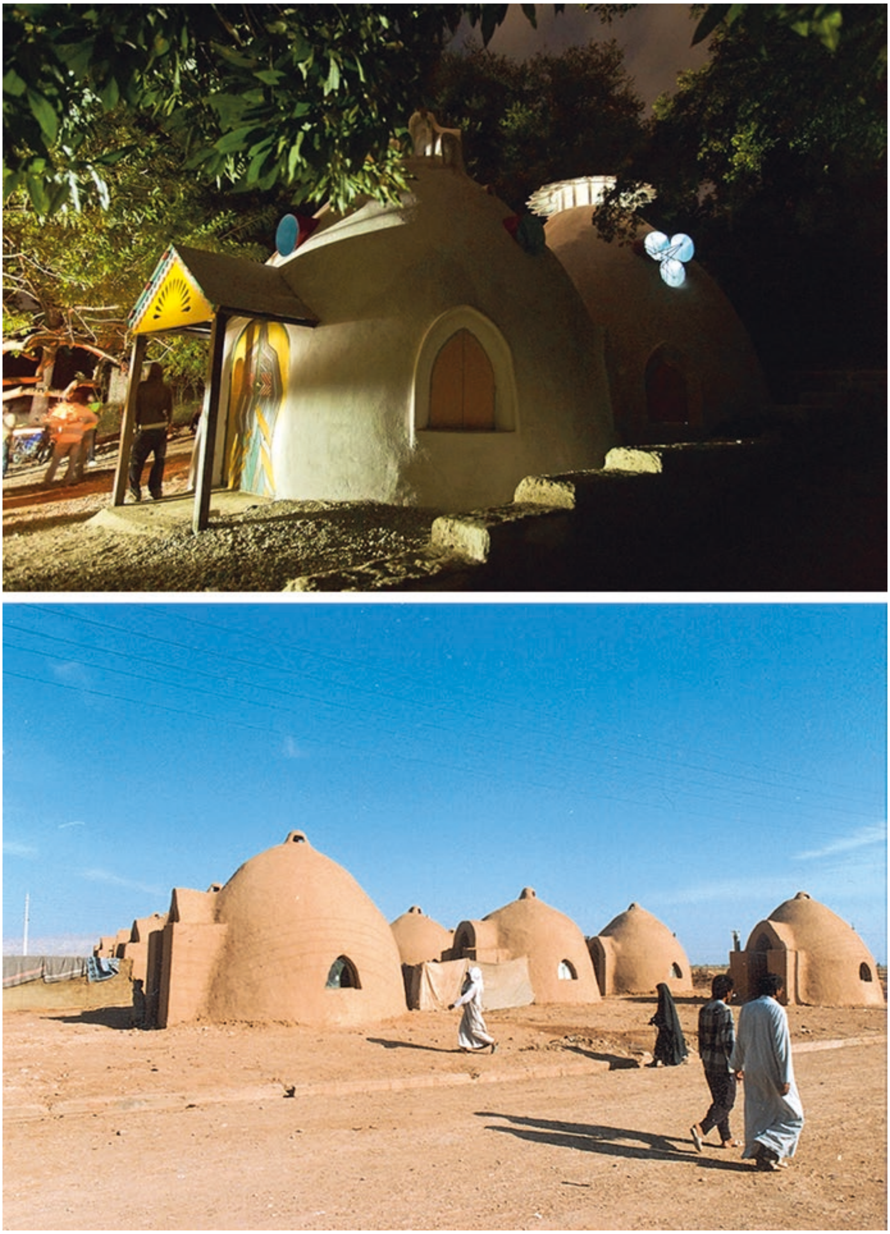

Fig. 14.3 SuperAdobe housing projects in Cormiers, Haiti (top image) (Konbit Shelter 2013c), and in Khuzestan, Iran (bottom image) (Cal-Earth Inc., 2016c). Photo credits Tod Seelie

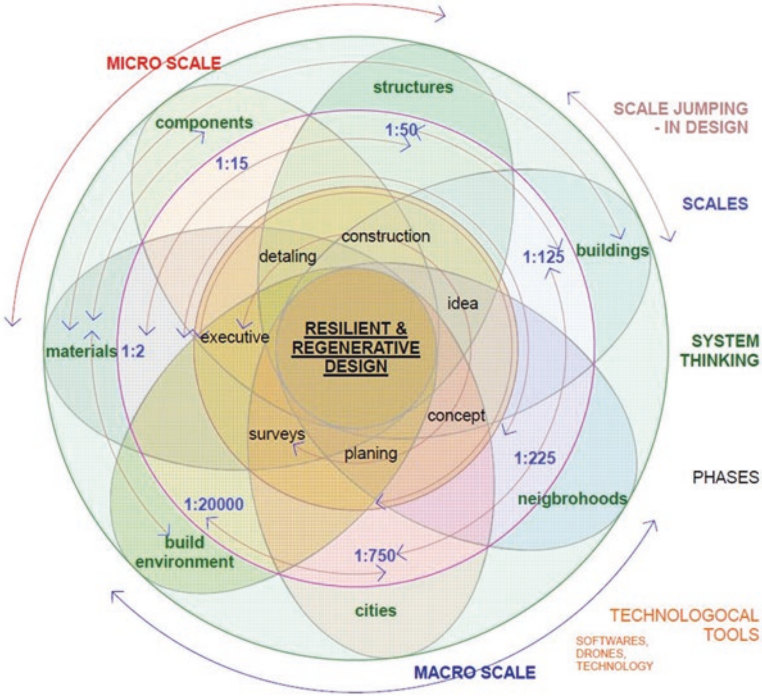

Fig. 14.4 Diagram of scale jumping during different phases applying systems thinking of the resilient and regenerative design process

Resilient and regenerative architecture offers a completely different approach to construction: the approach aims to allow anyone who is looking beyond the established trends of the building industry to create their vision for living in harmony with nature.

Synergies are available by making connections with the locally available materials, people and resources. Clay, silt, sand and gravel are commonly found at shallow depths between the bedrock and the organic topsoil. The different soil combinations in the right proportions create one of the greenest and most durable building materials known to man. Such organic building methods create a connection with the place by utilizing parts of the local geological history. The principles of resilient and regenerative design not only make use of what is locally available but also create new resources that can be adapted into new building solutions at both the scale of single buildings and large cities.

Implementing concepts at both the microscopic and macroscopic scales will improve the social, spatial and environmental dimensions of living as a part of nature. Resilient and regenerative design cooperation, collaboration and coordination will address the need for actions to mitigate interrelated vulnerabilities and can build resilience against the climate crisis and regenerative environment against environmental degradation.

Understanding and implementing the concepts of regenerative and resilient design in theory and practice are necessary not only for new architecture but also to consider the opportunities of retrofit architecture that will improve building performance by designing innovative, architecturally significant buildings from existing structures.

We can conclude that there is a need to assess building projects based on the lifecycle benefits that resilient and regenerative design brings at all scales from materials to the built environment. All elements of the built environment from the microscopic to the macroscopic scales and adjoining systems must integrate to adopt new flexible concepts to respond to unforeseeable future challenges. New possibilities need to be considered to improve regenerative and resilient architectural design strategies for intelligent building retrofits. New building life-cycle analysis rating tools need to be developed and effectively used. Multi-disciplinary teamwork using an integrated design approach is necessary to promote, cooperate and work towards creating regenerative and resilient architecture and cities using an iterative process keeping resilience and regeneration of buildings in cities and buildings as a core value. An in-depth needs analysis is essential for the continued success of projects after completion.

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