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RESILIENCE AND SUSTAINABILITY IN ARCHITECTURE

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ABSTRACT

This dissertation aims to approach the understanding of how resilience and sustainability can go hand in hand, and it is the future requirement to build resilient structures that are sustainable. Sustainable design and design for resilience to climate change emerged independently from each other, but their acknowledged correlation gets an increasing importance. This chapter investigates interrelations between sustainable and resilient design realms by comparing their key postulates and analyzing key objectives through the prism of mutual (in)consistencies. In this regard, the work presents both general observations and detailed considerations where specificity and complexity of relations between sustainable and resilient building design are found. Also, how the sustainability is misunderstood, and some old practices are studied that that supports the concept of dissertation and have shown through case studies. Results demonstrate that sustainability and resilience display complementarity rather than inconsistency in relation to each other, which leads to the conclusion that their integration into an outreaching, systemic approach is highly possible.

And to understand the different aspects of how it can be done different case studies have been done of structures which have different features that call be together can be to get the desired results.

INTRODUCTION

1.1 Basic information

Critics and scientists describe the era we live in as the Anthropocene, the sixth extinction. The human ecological footprint affects the earth in such a way that at the current rate of resource consumption we would need 1.6 terrestrial planets. This understanding goes beyond the concept of the environment Pollution as a cause of human activity or anthropogenic climate change to one in which humans' population has reached a point of unsustainability. In this situation where climate is also deteriorating day by day and disasters are one of the important concerns.

As an architecture student when started researching about sustainability and its impacts and limitations, the term resilience appeared in front of me because CFLs and LEED certification does not matter if a building becomes uninhabitable due to flooding, earthquake, or some other disaster. That is where building resilience comes into play. Resilience has many parallels with sustainable design. As National Institute of Building Sciences' senior vice president Earle Kennett stated in his lecture, one cannot consider resilient buildings and infrastructure without considering the natural environment and its own ability to bounce back from disasters.

The study of the relationships between architecture and values, can serve to help architects create the conditions conducive to sustainable, adaptive, and resilient architecture. The changes in these relationships tell us about the ability of architecture to impact socio-economic political and environmental aspects of life for all the inhabitants of the earth. In studying the object of architecture, one must also understand the system of knowledge that produced it.

1.2 RESILIENCE IN ARCHITECTURE

Now understanding resilience in architecture, Resilience is a strategy to enhance the ability of a building, facility, or community to both prevent damage and to recover from damage. Architecture can reduce the climate footprint and protect buildings and urban areas against climate change. Climate change calls for stronger initiatives in the building and construction sector – both to promote broader use of sustainable solutions and to make our buildings and cities more resilient to climate change. According to the Resilient Design Institute, resilient design is defined as "the intentional design of buildings, landscapes, communities, and regions in response to vulnerabilities to disaster and disruption of normal life". To design a building with resiliency means to start the design process by thinking carefully about the typical use scenarios of the building, common points of stress due to normal use, as well as the most likely disaster situations in the environment that could challenge the integrity of the building and/or endanger its occupants. The local environment always plays a critical role in determining the factors that make a building resilient or not, and so resilient design is always locally specific.

For example, New York City has a wet climate, and water is a part of its environmental challenges throughout the year. In New York City, the most common and likely natural disaster scenarios involve water: hurricanes, flooding, storm surges, and blizzards. Resilient building in New York City needs to plan for all of these types of events, as well as the day-to-day stress that comes from significant precipitation year-round, high-humidity, and the alternation of humidity (in the summer), with extremely dry interior air (in heated buildings in the winter). Of course, builders in New York City also need to design to withstand seismic activity, high heat loads in the summer, power outages, manmade disasters like terrorism, as well as the normal damage that comes with thousands of people moving through spaces in rapid succession.

Other example, On the West Coast of the United States, seismic considerations are obviously much more of a concern, as well as fire danger. Thinking through every potential problem and possible disaster situation can be overwhelming for designers, which is why a sensible approach starts by examining the most likely problem situations and pulling from local wisdom, knowledge and experience.

1.3 SUSTAINABLITY IN ARCHITECTURE

Next is sustainability in architecture, Sustainable architecture is the use of design strategies that reduce the negative environmental impact from a built environment. Sustainable design is no longer the way of the future - it is all important at present. Sustainable design seeks to reduce negative impacts on the environment, and the health and comfort of building occupants, thereby improving building performance. The basic objectives of sustainability are to reduce consumption of non-renewable resources, minimize waste, and create healthy, productive environments. The Sustainable Development Goals are the blueprint to achieve a better and more sustainable future for all. They address the global challenges we face, including poverty, inequality, climate change, environmental degradation, peace, and justice.

Sustainability is “the ability of society to continue functioning into the future without being forced into decline through exhaustion or overloading of the key resources on which that system depends.” Although sustainability is one of the most significant concepts of this decade, influencing the design of global government policy, economics, energy resources, technology, manufacturing, community planning and architecture; the idea of sustainability is not new. radiational planning and building methods were often good examples of sustainable design in their time and represented good uses of local resources matched with local skills. In combination, they produced a built environment which met people’s needs. However, factors such as demographic growth, and shifts from rural to urban areas create an imbalanced population distribution, natural and man-made resource depletion, and significant changes in expectations and lifestyles, all of which combine, in their various ways, to erode the viability of traditional approaches to shelter provision. A building method that worked well in the past in its given context may have now become difficult to afford, build and maintain, and it may no longer meet the desired requirements of the family or community [Oktay 2001]. But it is essential to look to buildings in the distant past for ideas about how to build in the future. Indeed, before the advent of air-conditioning and other technologies that is now taken for granted, architects and builders had no choice but to create sustainable structures. In the late nineteenth century – before electrical heating, cooling, and illumination – architects used a combination of mechanical devices and “passive” techniques (which worked without electrical or mechanical equipment) to illuminate and ventilate the interior spaces of even high-rise and long-span buildings.

1.4 NEED

There are roughly two meanings in the notion of Sustainable Architecture. The one is buildings which physically last long, require little maintenance, and save in energy, utility, and disposal costs. These are the aspects of gentleness to nature and that of small load to the environment, hence contribute to the sustainability of cities and consequently contribute to the sustainability of the whole earth. This is the aspect of what sort of impact the human deed of constructing buildings renders to natural environment and ecology. These are largely engineering aspects. The second aspect is the way architecture and environment ought to be, in fostering man's spirit and soul, and make man as a spiritual being sustainable. That is to say that architecture should not only be justified for giving little negative impact to global ecological systems by being resource conserving and energy saving, but also it should have beauty and something metaphysical which could work on human soul [Wines 2000]. So, ecological design must struggle with ways to integrate environmental technology, resource conservation, and aesthetic content. A major factor contributing to the longevity of buildings that have survived from the past, is their fusion of nature and art. They had to be both earth friendly and beautiful to be worthy of preservation in the first place.

1.5 AIM OF THE STUDY

Aim is to study how resilience of climatic change and sustainable design are interrelated to

find that whether they can be integrated or not.

1.6 OBJECTIVE OF THE STUDY

To learn different strategies of resilient and sustainable structures.

To understand the need of the integration for future

To analyze the implementation together as a whole.

1.7 SCOPE

The scope is to provide a design solution for resilient sustainable structure which is the neeed

of the future architecture.

1.8 Limitations

- Only the architecture design perspective will be considered.
- The practical implementation and placement of strategies will not be studied.
- Environmental sustainability has been considered

1.9 Methodology

- The selection of the topic as per interest
- Understanding the integration of resilience and sustainability and its need through various research papers, articles, and books
- Finding the secondary case study
- Analyzing the case study and its implementation in the building
- conclusion

2 SUSTAINABILITY AND RESILIENCE

Sustainable design and resilient design are equally important and have a lot in common, but they are not synonyms to each other. Reducing the environmental footprint of building with sustainable architecture is important as the building sector contributes 40% of greenhouse gas (GHG) emissions. However, a LEED certification for green buildings become irrelevant if the building becomes uninhabitable due to natural disasters or emergency situations. Thus, resilient design and sustainability complement each other.

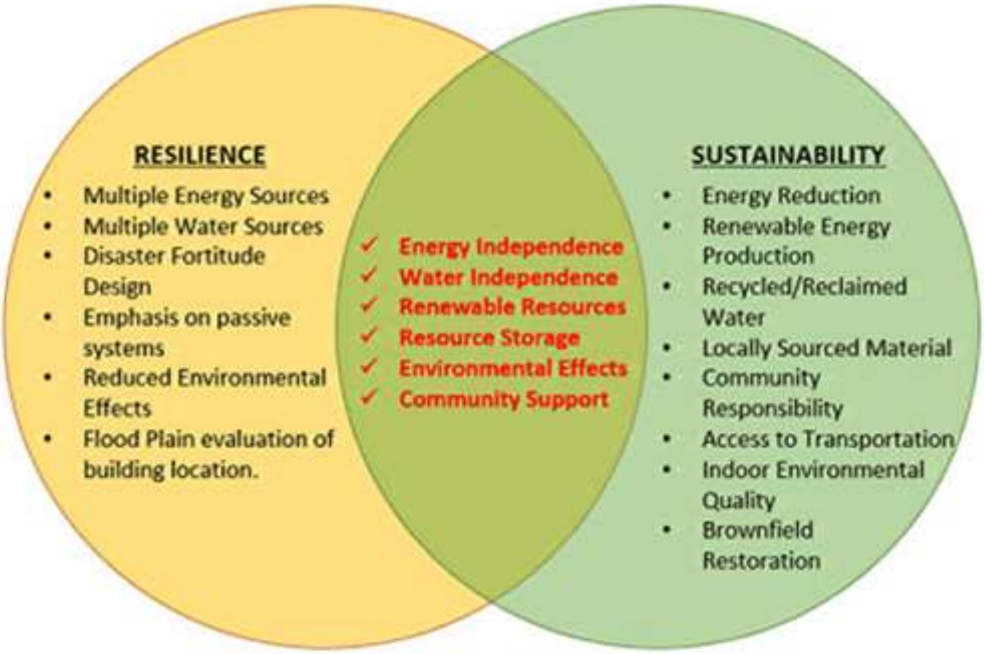


Figure 1; pie chart showing the similarities between resilience and sustainable design approach.

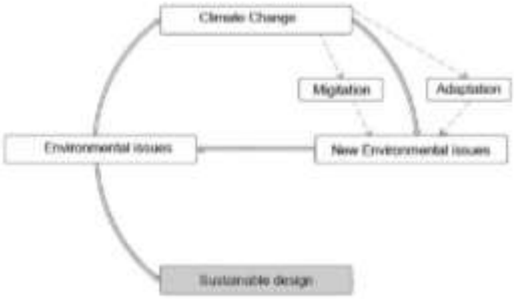
In architecture, resilience refers to a building's ability to withstand the natural elements (hurricanes, tornados, fire), while sustainability refers to its ability to reside in harmony with its natural surroundings (passive heating, cooling, minimal footprint). Often thought of as separate practices of these two terms. Today, in the face of climate change, architects are increasingly working with communities and experts to design structures that are more resilient and sustainable approaches can be integrated. Now architects are using their skills to not only design safer structures, but to also bring together experts, homeowners, and civic leaders to create safer communities for the future.

Even though the concept of sustainability has evolved over time, the basic principle is the same which is protecting the environment from the impacts of the human society. On the other hand, a resilient design is meant to protect the human society from the natural calamities to prevent disruption of normal life. When designing buildings that are sustainable and resilient, a lot of problems are faced. One must adhere to the minimal building codes. The local environment is one of key aspects that affect the building resilience. For e.g. Some cities are more concerned with hurricanes, while the others are concerned with earthquakes.

understanding sustainability from a different perspective that is to find the tangible and intangible meaning of it, the tangible meaning is the engineering practices of the system we are following day today life, but the intangible meaning is difficult to consider and is often omitted. From the environmental standpoint, sustainable design is brought to a set of well-defined engineering measures and scientific methodology aiming to treat nature as an external pre-given entity to be saved or exploited, even though it should be studied and understood from different perspectives. Environmentally sustainable design allows exact understanding, thought, causal explanation, classification, measurement, quantification, standardization, and optimization. nature is consequently transforming into a system in which stability and balance are accompanied by uncertainty and unpredictability.

nature is consequently transforming into a system in which stability and balance are accompanied by uncertainty and unpredictability. Climate change represents a clear evidence of natural shifts. To restore balance by mitigating climate change, sustainable building design provides a significant share of contribution through profound energy considerations. Despite such measures being taken, climate change continues to reinforce existing and create new risks, and to impact upon people and ecosystems, posing a potential threat to sustainability. When affected, the built environment generates new environmental issues. Complex and transformative causal relations between environmental (sustainability-related) issues, climate change, and new environmental issues in the built environment therefore represent a closed loop.

The approach to design for resilience to climate change has been developed independently of sustainable design. This is because of the most accepted meaning of sustainable design, which refers to the utilization of natural resources and to the consequent production of negative environmental impact. On the one hand, the two approaches offer opportunities for synergies and reciprocal benefits, while on the other hand, they potentially hinder individual validity and efficiency. In technical terms, the achievement of sustainability does not necessarily mean the achievement of resilience. When resilience is not developed, sustainability is called into question. Clearly, contemporary building design should respond to requirements of both sustainability and resilience. This work investigates relations between the two design realms, compares their key postulates and analyses their key objectives through the prism of mutual (in)consistencies. The aim is to provide an insight into critical interrelations and to reveal possibilities for the integration of sustainable and resilient design realms into an outreaching, systemic approach.



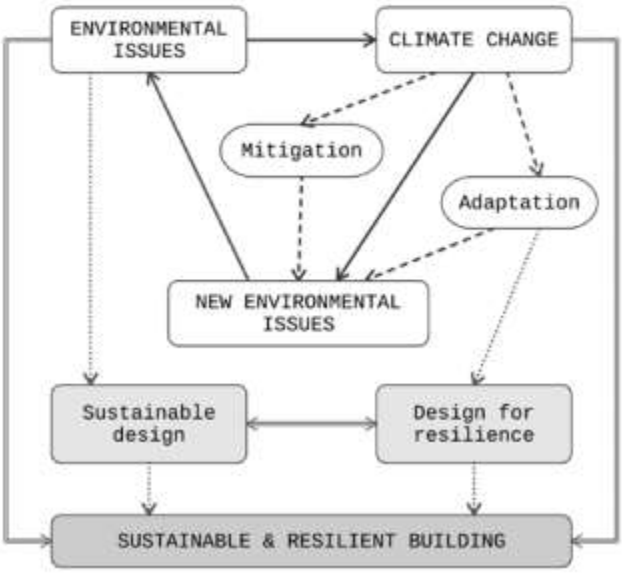


Fig 2; Inter-connection between environmental issues, climate change and design responses

From an environmental perspective, sustainable design refers to resource efficiency and reduced pollution. Sustainable building tends to lower the negative environmental impact to the minimum possible level while also using favorable environmental conditions for that purpose. On the other hand, a resilient system is represented by resistance and recovery, i.e., the ability to adjust to an unlucky condition, event, or change by absorbing disturbances and adapting to change without passing a threshold into a qualitatively different state. Resilience is the potential of a system to return to a baseline after being disturbed, or to reconfigure itself continuously and fluidly to adapt to ever-changing circumstances, while continuing to fulfil its purpose. Fundamental differences between the notions of sustainable design and design for resilience are underpinned by divergent sets of key features of these two approaches. Building performance represents a pivotal matter of concern to both sustainability and resilience, but it is addressed from two different standpoints. While sustainable design aims to reduce the impact of a building on the environment throughout the life cycle, resilience refers to the scope of impact of the environment on a building in the use and maintenance phase. This factual difference is identified as a base from which the potential for integration of sustainability and resilience design realms could be explored.

SUSTAINABLE DESIGN	DESIGN FOR RESILIENCE
Building rather viewed as a socio-ecological system (Guy & Moore, 2005)	Building rather viewed as a socio-technical system
Universally accepted environmental postulates	Postulates laid out in specific climate change manifestations
Reduction of impact from a building towards the environment	Reduction of impact from the environment towards a building
Whole life cycle consideration	Use & maintenance phase consideration
Developed methodologies for evaluation (measurement) of achieved sustainability level	Estimation of future behaviour dependent on predicted climate and weather events; Undeveloped assessment methodology
Contribution to climate change mitigation	Contribution to climate change adaptation
Efficient utilisation of resources	Shift in resources demand, secure supply and reduced dependence on external distribution systems
Bioclimatic and regional design	Regional and transposed regional design
Sustainable site design	Site designed to provide protection from direct and indirect climate change impacts
Sustainable building materials, components, and structures	Climate change-resilient building materials, components, and structures
Recoverability of a building and its parts	Recoverability of building operability
Occupants productivity, health, and wellbeing	Occupants behaviour, safety, and health
Optimised combination of sustainability measures	Robust rather than optimal solutions (Bakker, 2015); Redundancy
Durability and flexibility	Adaptability and transformability

Table no. 1 comparision of key issues of sustainable design and design for resilience

To define, describe, and predict the performance of a designed building, measurement and quantifications are needed from both sustainability and resilience perspectives. To measure the level of achieved sustainability, different life cycle assessment methodologies and assessment systems have been developed. On the other hand, methodologies for measuring the degree of resilience to (predicted) climate change manifestations are yet to be developed. To this end, argue that even sustainability systems still lack metrics that are repeatable, reproducible, and a true reflection of the building performance, and that the metrics for assessing the resiliency of buildings should be developed in tandem with sustainability metrics. By definition, sustainable building aims to preserve natural resources. On the contrary, a building exposed to climate change manifestations displays a shift in resources demand, requiring secure supply and reduced dependence on external distribution systems. Nevertheless, the primary concerns in both approaches are water and energy. While resilience refers to adaptation to climate change, sustainability targets climate change mitigation, although future climate change hazards may, at the present time, be indirectly addressed through measures for reduction of greenhouse gas emissions. As measures for climate change mitigation interact with measures for climate change adaptation, it is necessary to verify that these two sets are in synergy, and that they will not become contradictory and have negative consequences for each other in the future. In addition, sustainable design tends to use (sustainable) materials in an efficient way and to preserve free land, while resilient design concurrently aims to provide protection from direct and indirect climate change impacts, inter alia through adequate site design. Although location characteristics and corresponding site design are crucial for both sustainability and resilience, these two approaches tackle different subjects that should be compared and re-examined in order to establish an integration path, identify synergies, and remove potential mutual intrusions. In general, sustainable design aims to explore site limitations and potentials, while design for resilience primarily concerns risks to a building and threats to its occupants. As a result, integrated design for sustainability and resilience should consider all three key domains: threats, limitations, and potentials, respectively. Design that is adjusted to the wider spatial sustainability context and design that is in line with the wider spatial resilience framework – all round resilient design – together could be added to the 'positive fragment' approach.

SUSTAINABLE BUILDING SITE	RESILIENT BUILDING SITE
Climate and microclimate patterns	Changes in climate and microclimate patterns
Existence of urban heat island	Changes in extensiveness and intensity of urban heat island
Surface and relief characteristics, and water management	Surface drainage, flood, and erosion risks
Soil quality and composition	Susceptibility to erosion and the occurrence of landslides and soil subsidence
Distance from and spatial relation to existing pollution sources: traffic, industry, etc.	Identification of potential pollution sources in the case of extreme weather and climate events
Existence and protection of watercourses	Flood risk and water utilisation
Efficient water utilisation and water quality	Water availability
Renewable energy in situ for decreased emissions	Renewable energy in situ for decreased dependence on external sources
Urban infrastructural equipment	Infrastructural independence
Distance to public amenities	Distance and routes to safe locations and food supply grids
Distance to material suppliers to reduce transportation energy use	Distance to material suppliers for quick repair of the damage
Pavement characteristics: environmental quality of used materials, thermal behaviour, albedo, permeability	Pavement characteristics: thermal behaviour, albedo, water-resistance, resistance to extreme heat and cold, resistance to temperature shifts and solar (UV) radiation , permeability, provision of evacuation routes
Density	Porosity; Evacuation
Built structures in immediate surroundings	Hazards from built structures in immediate surroundings
Site reuse	Porosity
Efficient site occupation; Ratio between green and materialised surfaces; Porosity	Porosity
Characteristics of materialised surfaces: environmental quality of applied materials, thermal behaviour , albedo, permeability	Thermal behaviour, albedo, water-resistance, resistance to extreme heat and cold, temperature shifts and solar radiation, permeability, provision of evacuation routes
Characteristics of green surfaces; Vegetation type, position and surface; Protected and endemic species	Vegetation type and resilience
Outdoor temperature regulation	Reduction of heat load

Table no. 2 key subject of site plan of sustainable design and resilient design

Sustainable design largely depends on local context and issues of relevance and urgency Similarly, resilient design is driven by both gradual climate shifts and extreme events at a narrowed spatial level, to the micro-context in which a building is positioned). Both sustainability and resilience explore traditional solutions to climatic conditions, with the difference that resilience looks for design responses in spatial contexts in which forthcoming climate change manifestations have already been experienced. The system of a sustainable building consists of mutually balanced subsystems and elements that together provide optimized performance, even when their isolated behavior is not preferential. On the contrary, optimization is not a priority for resilience; rather, the system of a resilient building employs robustness and redundancy to counter uncertainty regarding future climate change manifestations. For climate proofing of new buildings and infrastructure within the robust approach, highlights synergy with mitigation, application of no-regret strategy, and reduced decision-time horizons. In such a way, the durability concept in a sustainable design framework could be impacted. Evidently, the discussion on resilience should be extended to include flexibility and durability considerations on the positive side, reduced decision-time horizons make way for new technological solutions possibly applied within the lifetime of a designed building Finally, both sustainability and resilience are future oriented, but led by different scenarios that evidently need unification. To carry out a profound discussion about the relationship between sustainability and resilience, responses to questions such as Resilience to what? i.e., Resilience for where? are needed. This work therefore presents general observations and deepened considerations where the specificity and complexity of relations between sustainable and resilient building design are found.

BUILDING MATERILIZATION AND DESIGN

Building Materialization and Design Sustainable design promotes rational spatial organization, decreased mass flows, and application of materials with satisfying environmental characteristics verified over the life cycle phases. Alternatively, the primary concern of isolated climate change responsive design is material resilience to water, fire, extreme heat or cold, solar radiation, pests, molds, and other hazards directly or indirectly induced by weather and climate events. Through the systemic considerations, building design should aim to employ materials that are both environmentally friendly and climate resilient, in order to avoid more damage and higher life cycle impacts due to lower hazard resistance. In this necessary integration process, expected climate change manifestations represent a starting point from which sustainability demands should be tackled. The amalgamation is especially challenging in the case of the application of alternative (mainly organic) sustainable building materials because of their resilience related characteristics, and the way in which they are embedded in building components and constructions. Design that encompasses both sustainability and resilience take into consideration the exposure of applied materials to weather and climate events. Clearly, climate sensitive materials should be positioned in non-exposed (protected) parts of a building. For example, in areas that are at risk of flood, water-resistant materials will be installed on lower floors of buildings, and flood-sensitive material types on the upper floors. In locations where extreme heat and heat waves are expected or have already been experienced, exposed materials should be resistant to the impact of high temperature, temperature shifts, and solar (ultraviolet) radiation. Regarding long- and medium-term temperature increase, the consideration of the thermal properties of applied materials is significant to both sustainability and resilience. In terms of resilience to extreme weather events, building components, constructions, and their connections are given equal importance as materials. Emerged duality between sustainability-related durability, and resilience-related robustness and linked purposeful reduction of service life could possibly be resolved with decreased exposure, increased resistance, and the approaches to design for disassembly and circular design, where particular attention should be given to the optimization of building envelope characteristics. It is expected that computer software and simulation will play a leading role in this intricate harmonization process. Sustainability and resilience to climate change shift conventional design logic and apply approach-specific design principles. The required integration aims to prevent occurrence of misbalance at the expense of either sustainability or resilience. For instance, to preserve valuable free land, especially in densely built areas, sustainable design promotes vertical development of a designed space, ultimately leading to the design of high-rise buildings from the standpoint of sole resilience, featured verticality could result in an increased vulnerability to climate change hazards. To this end, Mavrogianni, Wilkinson, Davis, Biddulph, and Oikonomou (2012, p. 123) explain that risk from overheating increases with the floor level, with top floors being warmest, followed by mid floor spaces. Besides temperature, changing wind patterns (such as peak loads or changing frequencies) could also manifest with stronger impact on tall buildings. Other design interventions that influence the achievement of both sustainability and resilience refer to occupant density control by design, determination of surface to volume ratio, definition of the building form, etc. Flood-proof architecture stands out as the most particular design expression in the context of resilience. The methods for achieving flood resilience encompass the following: design to avoid floodwater (dry flood proofing); design to allow temporary flooding of the lower parts of the building (wet flood proofing); and design for adaptable contact with the water – floating and amphibious structures. In accordance with location conditions, level of the risk of floods, building purpose, and chosen flood-proofing method, the design further considers existence of a basement space; introduction of stilts and mounds; positioning of building entrance, critical equipment, and communications and evacuation routes; drain-out measures; constructions, components and materials that are water-resistant, have good drying ability and low permeability, etc. The inclusion of sustainability-related postulates in design aims to prevent the adverse effects of one-sided choices. For example, the elevation of a building structure on pillars (above expected flood water level) decreases land occupation in conditions when there is no flood, but on the other hand increases the surface of the thermal envelope. Similarly, positioning buildings on artificial hills inevitably generates extensive earthworks; environmentally inadequate materials that get wet during the flood actuate new environmental impact through toxic emissions or leaching of hazardous substances, etc. By definition, the resilience of a designed building refers to its resistance, recoverability, and adaptability. Although adaptation is traditionally linked to external conditions, adaptable design was developed prior to the resilience approach, as evidenced by various experimental examples of static and dynamic (kinetic) adaptable design solutions that emerged over the course of the 20th century. More recently, adaptable buildings are considered as a possible response to climate change. In this regard, Sterner (2010) distinguishes between ‘passive resilience’ with given ability to absorb shock and remain in one regime, and ‘active resilience’ which displays the ability of a system to change its form in order to adjust to changeable external conditions. According to Loonen, Trčka, Cóstola, and Hensen (2013), a static, fixed, or nonflexible system has no in-built capacity to respond to changing conditions. On the contrary, adaptive design (most commonly manifested in climate adaptive building shells) could reconcile robustness, flexibility, and multi-ability, but the concept cannot yet be considered mature when regarded in terms of the many current challenges such as design and decision support, operational issues, and human aspects.

Time-scaling approach to resilience allows for the adjustment of architectural responses to temporal climate change variability and leaves space for the development of new adaptation technologies. Indeed, with the advancements in robotics and digital technology, novel dynamic sustainable and resilient models could be developed. To this end, Kohler (2012) proposed the ‘aerial architecture’ model where “structures can be designed to remain open-ended in order to be partially rearranged and dynamically adjusted over time… It is even possible that large buildings become displaceable ‘mobile homes’, fully or partially reusable in different locations and contexts, having second or third lives.”

ENERGY ISSUES

Buildings consume energy throughout all phases of their life cycle, but by far the greatest proportion of energy in buildings is used during the phase of use and maintenance Increase of average air temperature and the occurrence of heat and/or cold waves raise additional requirements for comfort provision, potentially resulting in impaired operational energy balance and increased energy consumption. According to results of the study that Crawley (2008) carried out by simulating the future impact of climate change in 25 locations around the world, the annual energy consumption in cold climates will be reduced by 10% or more. In tropical climates, total energy consumption in buildings will be increased, in some months even up to 20% compared to current trends. “Temperate, mid-latitude climates will see the largest change, but it will be a swapping from heating to cooling, including a significant reduction of 25% or more in heating energy and up to 15% increase in cooling energy” In accordance with the obtained results, Crawley (2008) emphasized the importance of changing the way buildings are designed, constructed, and operated, and, like Hallegatte (2009), indicated an unfavorable relationship between the future price of operational energy and the intensification of climate change. The adaptation to climate change should therefore avoid non-robust, high-energy consuming solutions, and instead aim for integration with mitigation measures and policies. Reduced energy demand, energy efficiency, and the use of renewable energy sources account for essential sustainable design attributes, which simultaneously contribute to climate change mitigation by reducing greenhouse gases emissions. Under the impact of climate change, the energy-related quality of a sustainable building may be deteriorated by additional operational requirements, from a small to a significantly large (extent. For this reason, even net-zero energy buildings should be designed using weather data that take climate change into account.

In a climate-resilient design context, the primary energy requirement concerns the stability of supply during and after the occurrence of weather and climate events. A resilient building responds to this requirement by reducing dependence on external systems and by employing energy systems that are resistant, adaptable, and sufficiently robust to overcome future climate change uncertainty. In this regard, and because of expected future increase in energy consumption, the greatest potential for integrating sustainability and resilience principles lies in the utilization of available renewable energy sources in situ, i.e., in the application of passive energy-related measures: natural ventilation and cooling, solar air and water heating, thermal mass, insulation, solar control, daylight, among others. Passive design concept plays an important role in reducing energy consumption, achieving energy efficiency, and decreasing dependence on external energy sources, but the resilience demands could nonetheless change the traditional utilization of passive systems. To this end, the main research question concerns the functioning of region-typical passive mechanisms in future climatic conditions. In principle, the performance of passive mechanisms applied to a building of certain type in the future, will depend on local climate change manifestation, as well as on their intensity and frequency. For instance, according to the predicted climatic temperature increase in Northern European, the application of passive solar design principles to maximize daylight and achieve solar heat gains will no longer be appropriate and new passive solutions typical of areas in which corresponding climate patterns are experienced, and adequate responses provided, could be used through a transposed regionalism approach as a basis for design redevelopment. In some warmer regions, like the Mediterranean, passive mechanisms used to combat increasing heat are already in place, just as the social adaptation that is deeply rooted in regional culture. According to ArupResearch+Development (2004), cultures in Northern Europe will have to alter their lifestyle to accommodate to the emerging climate change. Analogously, transposed regionalism may refer not just to architecture, but also to the culture, meaning that the social dimension of resilience inevitably calls for a change. When the threshold of habits and the capacity of traditional passive systems are exceeded (and for that reason become non-responsive to climate change manifestations), developed adaptation to the emphasized climatic parameters can easily imply new energy demands, which is why the passive measures in today’s design for the future should be maximized to the fullest. Passive energy measures in the sustainable design framework refer to the provision of heat, cold, and natural ventilation, and daylighting. These measures are embedded in the spatial organization of a building and in its components. Some passive measures, like solar water heating or daylight provision at the greater depth of a building, require installation of special elements, or utilization of specialized support equipment that, in the light of climate change, must be resilient. In resilience framework, the objectives of passive measures are translated to combating extreme high and low temperatures and reducing dependence on external energy supply systems. In terms of spatial organization, sustainable design employs spatial zoning and introduces distinctive spatial elements such as atria. Spatial zoning enables the physical separation of building areas that are exposed to variable environmental loads or characterized by different indoor regimes, e.g., the separation of naturally ventilated from mechanically ventilated zones, or the separation of heated from non-heated areas. As such, zoning is applicable to different passive solar heating techniques, enhancing the independence from external heat supply systems. In a world that is getting warmer, the role of spatial zoning in isolating internally generated heat and preventing its transition to other building parts is gaining importance. Alternatively, an atrium nested in building layout aims to enhance natural ventilation and introduce natural light deeper into the building space. With regard to natural ventilation, Lomas and Ji (2009) emphasized that simple natural ventilation methods such as cross ventilation will not be sufficient to combat internal heat gains in the future. Accordingly, advanced ventilation strategies were identified.

increase. While Kendrick suggest that it is possible to optimize lightweight buildings to provide thermal comfort using ventilation and shading, ArupResearch+Development (2004) demonstrated in their study that future temperature increase will result in near equalization of daily peak temperature in a lightweight building and peak external air temperature, and that a heavyweight system performs better when exposed to same warming conditions. Evidently, the estimation of passive system performance in the future depends not only on climate change patterns and building characteristics, but also on what research method is used. In colder climates, climates with both cold and warm seasons, and climates with large diurnal changes, lightweight constructions require more energy for thermal comfort maintenance, wherefore the priority in current practice is given to heavyweight systems. When applied, building thermal mass requires appropriate exposition with regard to orientation, as well as the introduction of other passive measures necessary for its regulation and ventilation.

Besides (changing) microclimate characteristics, and the interaction of building systems with climatic parameters and weather events, the decision-making between lightweight and heavyweight constructions should be informed by their sustainability quality throughout the life cycle. In comparison with heavyweight passive systems, lightweight constructions in general have less embodied energy and are less material intensive, but often require more maintenance, are more susceptible to damages during the extreme weather events, and have a shorter service life which, on the one hand, enables a robust approach to resilience, but on the other hand raises new material demands and therefore requires additional circularity studies. A construction that contributes to reduced energy consumption and comfort maintenance in a passive way, now and in future, should therefore reflect a solution that is optimized for robustness, and energy and material issues. The parameters of air, heat, and light comfort, due to their interconnectedness, require simultaneous consideration in sustainable design. The interactions between comfort parameters, however, are compounded by the impact of the changing climate and the behavior of occupants whose role in achieving even energy sustainability is still insufficiently predictable. Despite all design efforts to meet sustainability and resilience demands at the same time, it remains possible that climate change will cause the comfort zone to be extended, especially at locations characterized by significant temperature increase and the existence of urban heat island phenomenon. The recognized doubt can be resolved only by creating a new balance between design interventions and through profound new studies on whether the passive systems will be able to reach even expanded comfort conditions. To that end, it is important to initiate change in occupants' behavioral, physiological, and psychological responses, and to concurrently consider the application of robust solutions that show little variation with alternating occupant behavior patterns.

The building envelope is the recipient of benevolent outdoor conditions, inter alia by acting as an integral part of passive energy mechanisms. Concurrently, the envelope provides protection from external negative impact. Although these attributes may be given different priorities in the two approaches, they are equally significant in relation to energy considerations and as such require balancing. In the sustainable design framework, envelope plays an important role in reducing operational energy consumption and maintaining indoor comfort. Envelope energy performance is determined by a number of parameters such as heat conductivity, absorption and accumulation, insulation, airtightness, glazing characteristics (size, positioning, U-value), window to wall ratio, reflectivity value, solar control, application of greening systems, and others. In a changing climate, the envelope should be resistant to the damages caused by extreme weather events and responsive to the likelihood of reduced heating and increased cooling energy demands. This fact initiates the change in current envelope design practice and, having regard to the uncertainty of future climate change manifestations on the one hand and sustainability-related demands on the other, indicates time-scaled adaptable solutions by which incorrect climate change projections can be dealt with by treating non-structural adaptations as a method of nullifying the risk. In this context, interest in switchable nanotech materials could be increased in future research. Both heavyweight (high-mass) and lightweight (low-mass) constructions are common passive measures used to achieve thermal comfort in the indoor environment. Lightweight constructions respond quickly to temperature changes. For that reason, and when coupled with other passive measures, low-mass constructions are suitable for current warmer climates with low diurnal changes. Nonetheless, current lightweight systems design should also consider future temperature.

THE SOCIAL ROLE OF ARCHITECTURE AND THE ARCHITECT

John Ruskin described architecture as an art form that contributes to the mental health, power, and pleasure of its consumer. He drew connections, that resonate with environmentalist and sustainability movements of today. Louis Sullivan said that "form follows function". A product of his time, Sullivan emerged out of the Chicago school of thought, that emphasized simplicity in design. The theoretical debates that have shaped the history of architecture, have revolved around questions of aesthetics, form or function, and utility. The focus ought to be on the role that architecture can play in reestablishing the relationship between humans and their environments, to make them more consciousness. Architecture goes beyond that functional aspect of visually pleasing aesthetics, but that it must be understood as a form of human science. As such the role of the architect and architecture in society is a multifaceted one that encompasses the expression of values as well as value generation. Throughout history paradigm shifts in architecture have been shaped by scientific, technological, and critical thought advancements which forced the specialization of this profession and the departmentalization of the construction process itself.

History

From Modernism to Neomodernism

There is no doubt that industrialization has the most profound impact on the plant and human life, no other paradigm in history has impacted the natural environmental system, in terms of magnitude. Contemporary conceptualizations of architecture are often separated from the actual skill of construction and focused on the art and technique of designing. This can be traced back to the era of industrialization which brought about the separation of engineering from architecture, due to mass production. Major architectural undertakings would often be attributed to one individual who assumed the role of both chief engineer and chief architect. Thus, with the advent of the new types of societies that industrialization brought with it, the role of the architect retreated to ornamental design and away from beauty within the form. This can also be attributed to the shift in social classes as the previous paradigm of renaissance architecture the focus was from and on the aristocratic class. The development in relationship to urbanization, must be based on a solid developing plan for the expansion of any city, based on a scientific analysis and approach. Moreover, modern needs such as the expansion accounted for the health of inhabitants by building central gardens and orienting the homes to maximize the sunlight should be a priority. The rise of the modernist movement was a reaction to the empirical paradigm of empires and colonization, simply a reaction to the colonial city. The master plans that would be imposed on colonized and later developing countries were rigid and often became outdated quickly. The modernist's concept plan was seen as flexible, as it was often based on policy instruments such as zoning and population density which would serve as a more useful tool for city planners, developers, and the like. The post-world war II reconstruction in Europe focused on creating a better socio-economic order based on the needs of middle class. This period also experienced the rise of industrial design as war time industries transformed to focus on consumer commodities. Design was based on the qualities of materials used, for example steel allowed the rise of international style of skyscrapers. That period was characterized by building as apex of art, craft, and technology. With a paradigm shift towards form and function rather than aesthetic ornament. Many of the architectural innovations that were once deemed aesthetic signs of prosperity and progress began to crumble, often due to vacancies. In 1972 when many of these modernist buildings began to be demolished, architect Charles Jencks declared the death of modern architecture. Movements such as structuralism, post-structuralism, modernism, postmodernism, and even sub movements such as brutalism, expressionist, phenomenology, or organic architecture ought to be understood as paradigms that shift with time and context. Prior to the paradigm shift towards postmodernism and structuralism, the idea of organic architecture, emerged significantly and defined by the environment and purpose.

Fig 3; falling water, F.L.Wright

In designed Falling Water, Frank Wright, centralized the question of man against nature, and emphasized the need for harmony between human habitation and natural world. Postmodernism saw the introduction of sub movements such as metaphoric, bio-morphism, and zoomorphic which focused on using nature as the inspiration for form and design. Often driven by anti-structuralism thought such as Martin Heidegger's application of phenomenology, which took a historical approach to the study of architecture, space, and experience. Whereas modernism much like the political movements at the time took an anti-historical approach to modernization. More recently, re-constructivism, saw the purpose of architecture to awaken the sense of the real, in a world where everything has been demonstrated to be an illusion. Architects can reawaken the sense of real environmental danger facing humans by designing buildings with this in mind. If future architecture is to serve a positive social and human purpose, the focus must be driven by environmental concerns.

Shifts in Architectural Paradigms

Within the critique of modernism and post-modernism architecture paradigm shift taken place is best understood as firstly, the good architecture is not a personal, philosophical, or aesthetic pursuit by individualists. Secondly, it must consider everyday needs of people and use technology to create livable environments. Finally, that the design process is informed by studies of behavioral, environmental, and social sciences. The following three paradigms are interesting to note for the purpose of understanding contemporary architecture. Critical regionalism can be understood in terms of anti-globalization, as the focus is to reintroduce the place and identity into buildings. Throughout this paper, the concept of regionally responsive architecture will be referred to in this sense. As critical regionalism rejected both the lack of locality in the international style, as well as the individualism and return to ornamented style of postmodern architecture. Deconstructive, ironically the birth of contemporary architecture in the sense of sustainability has taken place with this quasi-movement. For instance, the famous work of Frank Gehry, the Guggenheim Museum Bilbao in Spain, is hailed as one of the most admired works of contemporary architecture, even though it was completed in 1997.

Fig 4; guggenheim museum Bilbao

Neomodernism is important note as history has shown the shortcoming of modernization theory and modernism in architecture. The foundation of addressing human needs through the scientific method remains a vital tool. As a movement, it rejects the complexity of postmodernism and focus rather on simplicity, with focus on functionality. Prior to the financial crisis, the types of buildings built can be characterized as part of the height race. Who could build the tallest building? The intent was to demonstrate economic prosperity and attract more investments. However, the sustainability of these types of buildings remains the main issue.

Smart Growth Cities

The concept of smart cities is ambiguous, as there are varying ways of describing and labeling a city smart. A notion, that attempts to integrate the use of information and communication technology (ICT) for the use of urban development. A smart city is one that is compact to limit urban sprawl. More importantly architecture needs to be responsive, on a regional and community needs basis as well as on an environmental level. In exploring the links between smart sustainable growth and development or underdevelopment, many interesting methods arise. Lack of data is one of the stumbling blocks that face the affective application of development projects and programs. However, what is equally fascinating is the quantity and rate at which the use of mobile devices has grown within emerging markets and regions. Although there is not formally collected and centralized, and often skewed, government certified data, individuals acting as a collective on an online network produce equally useful data. With applications that can vary from which regions lack infrastructure to how should we redevelop the inner-city roads to mitigate growing traffic. Public private partnerships between network providers, the government, and the communities can foster data production that can then be used to implement effective projects. There remains much research needed into the application of ICT.

However, by exploring the use of the ICT, the untapped potential for delivery better and more effective development assistance becomes apparent. Innovative techniques and methods can allow for the achievement of the SDGs more efficiently. The entire country of Bhutan has surpassed the concept of carbon-neutrally and is now the only carbon negative city in the world. The state’s leadership hope to eventually create a zero-waste economy, with zero-net greenhouse gas emissions and 100% organic food dependent. Currently the country is estimated to only create 1.5 million tons of carbon, while its forest absorbs six million annually.

Contemporary Architecture

Today's architecture is unique in that there is no dominant style, but what tends to be common, is the application of advanced technology and building materials. The advent of computer design programs has allowed for taller, stronger, and lighter buildings to be modeled tested and constructed faster with higher degrees of precision. The complexity of buildings has increased in terms of structural systems, services, energy, technological needs. The field of architecture has become multi-disciplinary with specializations often split between design and project architects. Drawing in teams of architects to maintain compliance with cost, durability, sustainability, laws, and quality. Perspectives to consider, such as metaphoric architecture, new classical architecture, and specifically new urbanism, are not new but rather they were marginalized with the advent of the automobile and wartime industry thinking. Today there is a need to return to responsive approaches that realize the social dimensions of architecture.

Sustainability: New Classical or New Urbanism? The idea of sustainability is not new, although it may appear as a recent phenomenon in construction practices. Such as local laws that now adopt indicators and measures from Leadership in Energy and Environmental Design (LEED) certifications. But sustainability alone is not enough at a functional level. Several architects revolved around ecological design. They focused on efficiency and energy, as it pertained to the features, placement, and aspects of a building in terms of heating, cooling, powering, venting, lighting, feeding, watering, and sanitation. Today we understand these notions in terms of energy efficiency with a focus on carbon-neutral or even productively creating energy for self-sufficient use (autonomous buildings). The overarching focus is on positing architecture within a broader socio-cultural framework that considers the dependency relationships between humans and nature. New urbanism promotes a sustainable approach towards construction in terms of practices as well as a shift away from solitary estates that only increase suburban sprawl. With a focus on creating the spaces and conditions necessary to promote sense of community and ecological sustainability. Notions of sustainable growth such as transit-oriented development (TOD) and principles of intelligent urbanism (PIU) will be explored next, as the future of these theoretical perspectives in practices will be to promote and create smart cities. It is important to note, that the focus on the future of architecture, cannot be dominated by the sole notion of sustainability, and should incorporate notions of adaptability and resilience.

Recognizable Standards: Leadership in Energy and Environmental Design (LEED)

LEED is one of the most used green building certifications globally Overall the savings from lower operational costs associated with LEED certified buildings mitigate additional costs of design and construction. However, it is important to note that LEED certified buildings alone cannot create sustainable conditions. There is also a need to implement sustainable design thinking within the urban fabric. Critiques such as Jeff Speck emphasis the negatives of building-centric certifications. That it promotes a culture of building practices, that tend to ignore external realities, such as location and placement, which could work against the whole point of building sustainably.

Figure 5; Art Center Greensburg, Kansas, USA, LEED Platinum

After a tornado destroy the town of Greensburg, Kansas (USA), the community decided to rebuild following LEED platinum environmental standards. Featured is the town's new art center, collecting solar and wind energy for self-sufficiency. Recently, the International Living Future Institute, has developed its own certification which builds on much of the success of LEED. The living building challenge is considered to be more rigorous performance standard for buildings.

Intelligent urbanism

Principles of intelligent urbanism is a theory of urban planning that evolved out the of guidelines provided by the International Congress of Modern Architecture (CIAM). Described as a set of axioms, laying down a value-based framework, within which participatory planning can proceed. The key take away is that effective technology application and engagement with the local communities during planning, leads to the fostering of collective intelligence as well as human capital. Both of which are fundamental to creating the social conditions necessary for sustainable change.

Powered by a low carbon emitting tri generation power plant and featuring an internal water recycling plant, which filters rainwater from the roofs, ground water from drainage systems, sewage from the public sewer, and drinking water from the main water systems. The building comprises its own shopping mall and other amenities to promote local walking culture.

Figure 6; One Central Park featuring hanging vertical gardens, Sydney.

This is a great example of integrated urban water management philosophy, that applies the management of all forms of water, fresh, storm, waste or grey, into the flow of the water and sanitation supply. Also, the featured hanging gardens, plays on to the concept of vertical farming. One that applies the methods of hydroculture and horticulture lighting and integrates the reuse of water, into creating features, that could potentially feed the inhabitants of the buildings. The following selected six principles are important to highlight.

Principle One: A Balance with nature, emphasis the utilization, enhancement, and conservation of natural resources as opposed to exploiting them.

Principle Two: A Balance with tradition, emphasis value and respect for vernacular architecture, use of local resources, and precedents of patterns and styles.

Principle Three: Appropriate technology, goes beyond the appropriation of technologies, and emphasis the matching of interfaces. Finding the ideal balance between physical limits of urban services, administrative and electoral boundaries. As such to be in line with the local people in terms of absorption capacities, geo-climatic conditions, and local resources.

Principle Four: Efficiency, emphasis the optimum sharing of energy, time, and public amenities, to reduce individual household costs.

Principle Five: Human scale, emphasis walkable, pedestrian oriented, urban arrangements, with a focus on accessibility.

Principle Six: Opportunity matrix builds on the emphasis of accessibility, by treating the city and urban arrangements as a vehicle for personal, social, and economic development. Bringing together opportunities for education, relaxation, health, safety, and employment.

Transit Oriented Development: **TOD**

TOD is a form of urban development that maximizes the economic, social, and political spaces within walking distance of public transit. Although the emphasis is on use of public transit, the greatest observable shift in transport habits, is from automobile use to walking. The new habitable environment encourages regular exercise and an overall increase in health. This environmental shift in urban organization, offers the greatest return on public health, on the individual level, as well as on the health care system. On an ecological level, overall energy emissions are reduced, and there is an observable decrease in air pollution from automobiles. This can offer many health benefits.

Energy system in Buildings

Net-Positive Energy production- Although, complicated notions, sustainability, and sustainable development, can both be simply defined in terms of meeting the demands of today, without compromising the needs of tomorrow. As such, productive and sustainable architecture, can play a role in shaping resilient and adaptive buildings that transcend current needs and looks to the future. Autonomous buildings, are designed to operate independent of public infrastructure, meeting their own demands through passive and active techniques. Bed ZED is a carbon-neutral eco-community, featuring solar panels and passive ventilation chimneys. There is a growing focus on net-zero energy use buildings, which means the building creates the energy needed and can produces extra for the grid. Moreover, there is a growing focus on streamlining carbon neutrality in all aspects of buildings to reduce carbon and ecological footprints.

The passive standard combines a variety of techniques and technologies to achieve ultra-low energy use for heating or cooling. Designed to reduce a buildings ecological footprint. Incorporating the basic building blocks of cities namely, water, energy, and food, into self-sufficient thinking, shows positive potential for its inhabitants or users. The application of various techniques such as, net-positive/zero energy production, vertical farming, IUWM, and passive/active solar collection, must be at the core of the architectural design process.

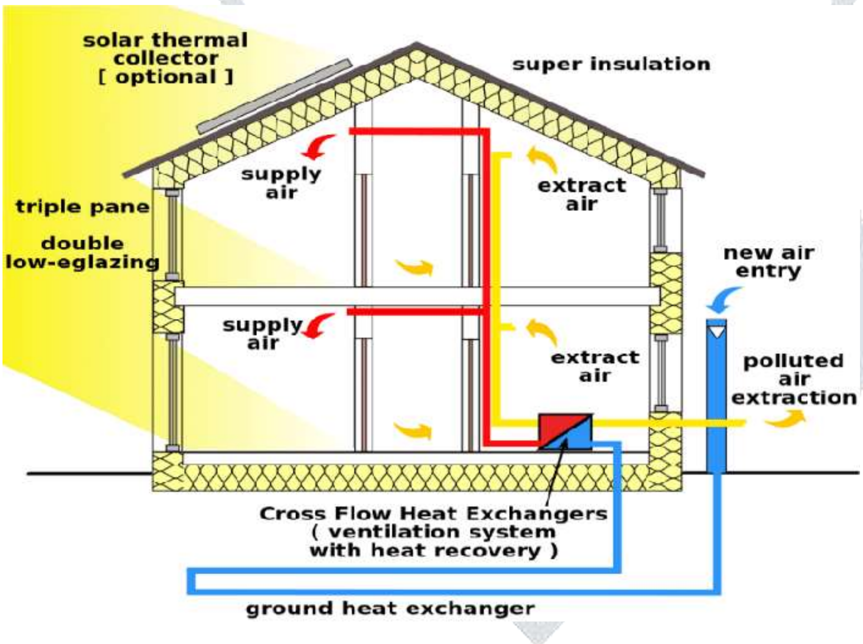


Figure 7; Diagram of the science behind the passive method

CASE STUDIES

1. THE AFOREMENTIONED HURRICANE STRONG HOME

Client: Diane Hellriege

Healthcare Size: 1200 square feet

Completion Date: 2015

Designed and built - Azaroff and a team of national experts.

Resilience –

- The house is elevated more than 3-feet above average flood elevation.
- With open concrete posts sunk deep into the ground and vents that let flowing water easily escape underneath the house.
- The walls and floor are made with concrete-filled forms made from polystyrene and recycled plastic that can withstand driving rain and 300-mile per hour winds.
- It has fire-resistant fiber cement-board siding and inflexible, interlocking polymer roof shingles locked in with screws.
- Safety glass and steel shutters in the windows can withstand a 9-pound piece of wood flying at 34 miles per hour.
- And the roof is held in place with ultra-strong connectors.
- At the house’s center is a concrete and steel reinforced space that includes the kitchen, bathroom, laundry, and an emergency supply closet.
- There is a cistern that captures rainwater and filters it, solar panels for electricity, a sun tunnel that can be opened or closed for natural light and Murphy bed.
- 5 to 30 ft vegetation free zone against fire.

Fig 8; the aforementioned hurricane strong home

Fig 9; the hurricane strong home plan

2. K2 SUSTAINABLE HOUSING WINDSOR VICTORIA, AUSTRALIA

The K2 Sustainable Housing Project is the first private recycled water scheme in Victoria. Located in Windsor, in Melbourne's inner south-east, K2 is a social housing project with a commitment from the Victorian government to go 'all the way' on environmentally sound design and performance without compromise.

The award-winning K2 Apartments located in Windsor began as a design competition in 2001, which was won by Design Inc Melbourne. As well as environmental performance, the design brief called for an emphasis on the social and economic aspects of sustainability. It resulted in a 96-unit public housing development which has led the way in sustainable design for medium density developments.

Passive solar design led to four connected buildings on the 4800 square metre sites. The four buildings were oriented on an east-west axis to allow for maximum northern exposure. The height of the buildings and the distance between the front and back pairs was calculated to ensure all units received northern sun for natural light and heating, particularly in cooler months.

In addition to the energy efficient building envelope, roof-mounted solar panels, efficient lighting systems, individual sub-metering, energy efficient lifts and a roof-mounted gas-boosted solar hot water system were installed. The building was completed and tenanted in 2007.

The design brief required that the building meet some ambitious targets.

- 200-year life span.
- Ability to generate renewable energy on site.
- Consume no non-renewable energy.
- Halve average town water use.

The goal was set for each of the 96 apartments to require: 55 per cent less mains electricity, 46 per cent less mains gas and 53 per cent less mains water (including irrigation) than a standard apartment each year.

Fig10; K2 housing apartment, Australia

❖ Water

Rainwater is collected, treated, and stored in rooftop tanks to supplement domestic supply. Grey water is recycled for gardening and toilet flushing.

Water-efficient fittings and fixtures such as AAA showerheads reduce water consumption, and water meters are installed in each unit to monitor water use and educate tenants. 'Water smart' gardens have been designed that need little water.

All these measures will reduce mains water use by approximately 53 per cent compared to an average apartment of similar size.

❖ Materials

Materials were chosen because they were recyclable, robust, non-toxic, and did not produce much waste. Health of the environment, particularly of tenants, was an important consideration.

Timber was either reused or came from sustainable managed forests, and fly ash (a coal combustion product that is more durable and produces less greenhouse gas emissions than cement) was used instead of cement in concrete. Non-toxic paints and floor finishes were used, assuring high indoor air quality, while natural finishes reduce maintenance needs like painting and varnishing.

❖ Energy and solar power

The height, position, and windows of the four buildings have been carefully chosen so that they are a comfortable temperature all year round.

Exposed concrete ceilings and heavy walls provide thermal mass to help maintain a stable temperature indoors, while insulation, double-glazed windows and shading prevent heat loss and gain. Energy-efficient fittings, such as fluorescent light bulbs, are installed throughout the apartments.

❖ Summer

Cross-ventilation cool the apartments and fans, and ventilators carry away built-up heat.

❖ Winter

The buildings are oriented so that all units receive northern sun, reducing the need for heating. There are a limited number of windows on the south, east and west sides of the buildings to reduce heat loss through the glass. The buildings are well sealed and insulated, and screens beside the access balconies provide protection from the weather.

❖ **Solar power**

Roof tops are angled to face the sun so that photovoltaic (solar) panels can collect the maximum amount of energy, and provide some shade. Solar power heats at least 50 per cent of the buildings' hot water.

❖ **Landscaping**

Approximately 20 percent of the K2 site is dedicated to landscape gardens. 'Water smart' gardens drain water to areas where it is most needed, and filter stormwater before discharging it from the site. The gardens use drip irrigation from the grey water supply.

Mostly hardy native plants were chosen that suit Melbourne's dry conditions and the amount of sunlight in each space. A mixture of deciduous and evergreen trees was chosen to provide shade or allow sunlight in, as needed.

Fig11; K2 housing apartment, Australia

When you take the approach, as we do, that the built environment can be an extension of the natural world, not just an adjunct to it, you find exciting possibilities everywhere.
Stephen Webb , Design Director

3. CASE STUDY - Spaulding Rehabilitation Hospital in Boston

Client: Partners

Healthcare Size: 260,000 square feet

Completion Date: 2013

Sustainability: LEED Gold

Resilient: SLR approved

Architect: Perkins+ Will, Boston and Chicago

Fig12; Spaulding rehabilitation hospital in Boston

Resilience

Sea Level Rise / Surges

- ❖ The ground floor has been elevated 42” above the current 100-year flood elevation and 30” above the 500-year flood elevation.
- ❖ All patient and treatment rooms are located above the first floor and critical building systems are located on the roof.
- ❖ An accessible entry canopy will allow emergency egress at the second floor during a flood event.
- ❖ Patient room Keyed operable windows can be opened for fresh air ventilation in case of mechanical systems interruptions.

Resilient infrastructure

- ❖ Outdoor hardened landscape features designed to reduce potential wave action and flotsam impacts during a coastal flood event.
- ❖ Despite the narrow miss of Hurricane Sandy, the hospital dealt with a different form of devastation just one year later.

Floods

- ❖ Elevating the access ramp to the below grade parking to a peak datum equal to the ground floor grade of the building so that the parking should not flood prematurely.

- Incorporating excavated granite blocks and live oak beams into the landscape design as reef-like barriers to mitigate storm surge intensity.

- Waterproofing fuel and fire pumps located at grade or in the basement.

- Elevating all vents at or above the ground floor flood datum.

Fig13; Site section - Spaulding rehabilitation hospital in Boston

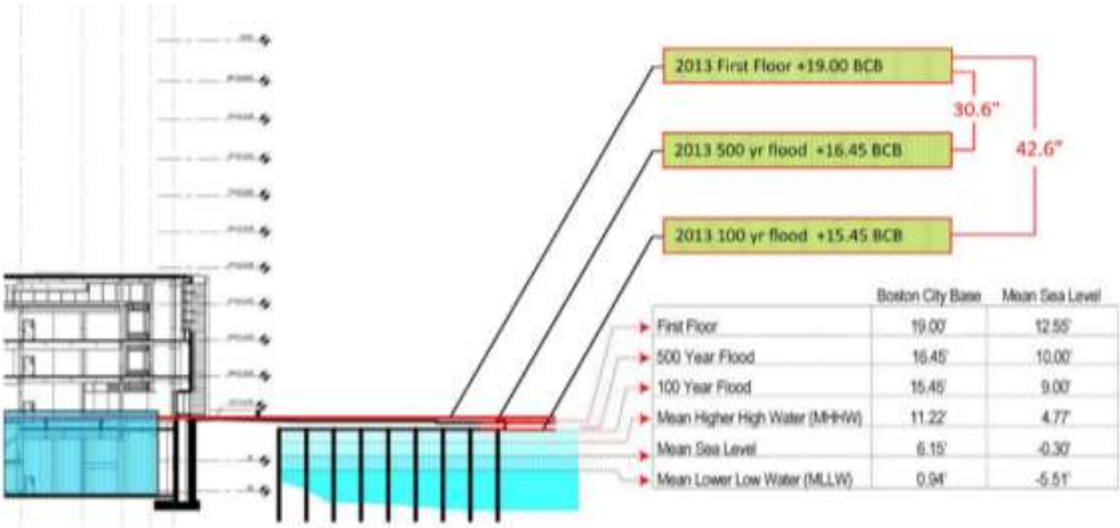


Fig14; water level - Spaulding rehabilitation hospital in Boston

Sustainability

Green Building

- LEED V2 Gold Certification Point: 44/69

- A high-performance envelope with triple glazed windows and exterior shading devices provides optimal thermal performance.

- The building is designed to maximize "free daylighting" in patient rooms and open office spaces.

- ❖ The gymnasia and social spaces are naturally ventilated via operable windows that turn off the HVAC system when the windows are open helping patients build stamina through exercising in ambient conditions.

Carbon reduction

- ❖ All the building systems and equipment are highly energy efficient and, with an onsite Combined Heat and Power system, translates into dramatically lower carbon emissions.

- ❖ With an Energy Use Intensity of 150 (kBtu /sf/yrs.), Spaulding is 25% below the specialty hospital average EUI of 206.7 (kBtu/sf/yr).

- ❖ After 6 years of operation, the hospital continues to improve its energy performance and further reduce greenhouse gas emissions.

	RESILIENCE	SUSTAINABILIITY
1. ENERGY IDEPENDENCE	Cogeneration – Natural Gas Fuel Cell, Heat is stored in different block	High Efficiency Chillers, Boilers and other HVAC Equipment, High Efficiency Lighting Fixtures, Heat is used for hot water reheat and for ice melt on site.
2. WATER INDEPENDANCE	Rainwater Collection for Irrigation, Greywater Collection	Water-efficient Plumbing Fixtures, Treatment for Cooling Tower Make-Up and Toilet Flushing using grey water.
3. BUILDING ENVELOPE	Plantings, walls, boulders act to dissipate energy of storm surge, Ground floor & openings set at 3.35' above 100-year storm flood level	Daylighting, Increased Insulation, Patient Rooms (Clerestory Windows), Reduced Glazing %, Natural Ventilation.
4. COMMUNITY SUPPORT	Operable windows keyed open in event of systems failure ,Mechanical, electrical & emergency services located within enclosed penthouse, out of harm's way	Access to transportation, community responsibility.

Table no. 3 comparative analysis

4 CONCLUSION

According to the Intergovernmental Panel on Climate Change (2014), "comprehensive strategies in response to climate change that are consistent with sustainable development take into account the co-benefits adverse side effects and risks that may arise from both adaptation and mitigation options" Hence, the notions of sustainability and resilience are built on different foundations. To this regard, Zolli (2012) observes, "Where sustainability aims to put the world back into balance, resilience looks for ways to manage in an imbalanced world".

The integration of sustainability and resilience design principles represents a challenging topic to accept and very difficult to apply. This work has demonstrated that sustainability and resilience display complementarity rather than inconsistencies in relation to each other, which leads to the conclusion that their integration is highly possible. Definitions and descriptions of such integration are yet to be developed. Among the few schemes proposed so far, for holistic understanding of sustainability and resilience, Sterner (2010) argues that resilience will be integrated into a holistic approach only when sustainable design is observed from the perspective of complex systems characterized by dynamics and nonlinear structure. In more general context, O'Brien introduce the term 'sustainable adaptation', referring to a process that addresses the underlying causes of vulnerability and poverty, including ecological fragility.

Sustainable and resilient buildings are not new architectural typology. Instead, they represent the essential quality of any building type. Until the principles of sustainability and resilience are fully merged with conventional architectural design, their character will be accentuated. At that point, the terminology used to describe the two approaches will become a part of regular designers' vocabulary. For the importance that sustainable and resilient approaches to design not doubtfully have, and the intricacies in current times, their incorporation into common design process and methodology is critical.

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