Research on Climate-Resilient Buildings for Severe Precipitation

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Abstract. One of the main questions raised by climate change to the global architectural debate was that "What were the determinants of the livelihood of residents and how could we approach them under severe and unstable precipitation phenomenon?" An essential priority of climate mitigation and adaptation is to combine meteorological lenses in an architectural approach. Former scholars had been focusing on the notion of resilience in sustainable urban development, primarily known as the ability of the urban system to recover from a disturbance. In this descriptive paper, the author reviewed partial literature titled both "extreme precipitation" and "urban resilience" in the ScienceDirect database and the Journal of the American Institute of Architects. This paper validated the use of metal roof hardening methods and green infrastructure in the construction in an attempt to provide applicable climate resilient design approaches to architects, city or regional planners, administrations, and stakeholders. Also, self-sufficiency, cost-efficiency, disaster safety shelters, and the mitigation and ever-adaptation to the local climate would have perpetuated the traditional approaches to heavy precipitation to an upper level.

Keywords: resilient city planning · extreme precipitation · flood design · climate resilient construction material · smart cities

1 Introduction

Weather forecasting is an important application in meteorology and has been one of the most scientifically and technologically challenging problems around the world. Modern meteorology was first defined and developed in the 1960s, with the installation of the first storm prediction system in the United States National Oceanic and Atmospheric Administration (NOAA). Its application has been in multiple fields from industrial production to medical therapies. Facing engineers, architects, urban planners, and policymakers are working through a collaborative framework for climate resilience cities. This research paper is intended to be a descriptive and review paper. So, the paper will focus on the topic of severe rainfall, storms, snow, tornadoes, etc. from both a scientific and a social lens. Then, the author will examine extant construction materials in the theoretical or practical architecture of great resilience and resistance in severe climates. Finally, the

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author will summarize some promising cases in building future resilient, sustainable cities and evaluate them from meteorological, architectural, and social perspectives. This study provides a reference for architectural design research in response to extreme climates.

2 Impact of Severe Weather and Flooding Watch

Serious flash flood events engender high precipitation efficiency, which is the ratio of the rainfall mass to the input water flux of clouds. These rains and thunderstorms are convective in nature when the highly moist air ascends vertically in a warm space [1]. The storms that can produce a flash flood have a slow movement and a large area of high rainfall rates along with their movements. Besides, the high rainfall was linked to human influences, according to experts at Lawrence Berkeley National Laboratory. Nonetheless, man-made changes in atmospheric circulation are difficult to detect and measure [2].

Despite the localized or regional convective conditions, the world had long suffered from severe weather events. Extreme weather events had challenged anthropogenic attribution to typical events since they are infrequent and frequently dynamically complicated. Nonetheless, numerous significant anthropogenic or natural climate change consequences exist. The Colorado floods of September 2013 are a vivid illustration of an unusual precipitation pattern delivering rainfall to a region of harsh topography, as well as a variation resulting in severe floods and utter devastation [2]. As a result of such incidents, Boulder, Lyons, Longmont, and other towns in Colorado, United States suffered. Only in Lyons, over 20% of houses were beyond repair, while 1000 residents found their homes uninhabitable [3]. Also, from the perspective of social media information and emotional communications, severe weather should be warned, and governors should convey a clear warning to the public. To supplement the point, researchers at Nanjing University of Information Science & Technology and the University of Manchester concluded that the negative remarks online about the flooding and damage recovery process appeared to help manage in-time regional strategies for the government [4].

3 Climate Change and Extreme Weather Forecasting

On May 27, 2022, representatives from 184 countries gathered in Bali, Indonesia for United Nation's Global Platform for Disaster Risk Reduction. The conference reviewed existing global measurements taken to prevent or even treat hazardous weather and other natural disasters. The UN Secretary-General, António Guterres, pointed out the importance of inclusivity of early warning systems and corresponding actions. The Bali Agenda for Resilience was signed to integrate disaster risk reduction in the conference and which would be taken forward to COP27, the G20, and the Sendai Framework Midterm Review. Among 184 countries, only 95 reported having multi-hazard early warning systems for catastrophes, which was not proactive in global warming. The systems were expected to take decent precautions against all the severe weather which was predicted to average 1.5 globally in a day by 2030, whether it be floods, storms, droughts, or volcanic eruptions [5].

The severe precipitation can result in catastrophic weather events. Rapid air rising with ample water vapor is thought to trigger heavy precipitation [6]. A severe thunderstorm, for example, has winds of at least 58 mph with hail larger than 1″ in diameter. Its threat included the strong likelihood of tornadoes. Meanwhile, the measurements, modeling, prediction, and prevention of severe weather events were progressing steadily in the past 100 years, as modern Meteorology developed. The European Centre for Medium-Range Weather Forecasts (ECMWF) reported a remarkable breakthrough in severe weather forecasting in 2006, namely the Extreme Forecast Index (EFI). It served as the calibration instrument of the Ensemble Prediction System, referencing the inconsistency in weather data without defining different space- and time-dependent thresholds. The researchers in ECMWF introduced the EFI as an extra weight term to the statistical Anderson-Darling test for revision of a temperature graph of an intense warm spell. The EFI modification helped the meteorologists to better identify the climatologically abnormal weather location-time data that should be analyzed more [7].

4 Resilience in Architecture and Construction Material

According to the World Bank, financial losses due to climate catastrophes have reached nearly 200 billion dollars per year. And the resilience of current or newly planned buildings has become an "increasingly important priority," said the division manager of LEED, the world's best-used green building system. Precisely, architecture is the new approach to reducing climate risks for future generations, and construction material has a rising significance in the process. The metals which are ductile, malleable, and of great electrical and thermal conductivity, are considered resilient and enduring materials in roof-building. Incorporating Polyiso at the Big Cottonwood Canyon Fire Station, in Salt Lake County, Utah, helped it meet IECC and ASHRAE Standards for climate zone 5B and improved its thermal efficiency [8].

Another frequent and deadly severe weather event discussed in this article is flooding. Building resilience to disasters in flood-prone areas is very much needed. Floods can

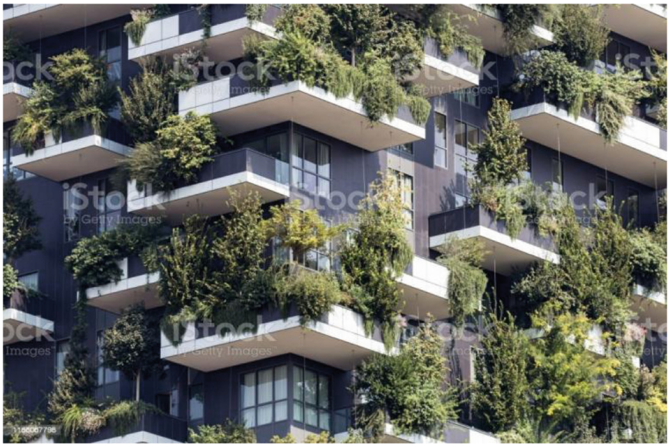

Fig. 1. Vertical City Gardens Credit: tostphoto (iStock) [13]

not only cause damage to buildings but also cause secondary disasters such as plagues. To tackle the challenge, varied green roof systems have been attempted in urban environments. The walls of buildings covered in plants can provide gradual absorption of rainfall, and thus improve the regional air quality. Such a technique requires interlocking blocks and some cantilevered volume for flood water, so that when the precipitation appears overwhelming the next time, the water can be maintained in the walls, and blocked by the extra height of the stair risers from the finished floor [9] (Fig. 1).

5 Planning Resilient Cities in a Meteorological Perspective

The case studies of Vietnamese floating settlements in MeKong Delta were indicative of a strong engagement of surrounding nature, but less concern in the preservation under rapid resource degradation and flooding attacks. Settled near the crisscross rivers in MeKong Delta, these long-established floating communities adapted to the humid tropical climate in consideration of walls, roofs, screens, floors, and openings. In the researcher's opinion, the flood-proof housing construction in Vietnam was based on decent site analysis to the optimal choice of sufficient natural resources and natural protection. Instead of the architectural characteristics, the researcher elaborated that self-sufficiency, cost-efficiency, disaster safety shelters, and the mitigation and ever-adaptation to local climate were more compelling determinants of urban resilience [10].

In a broader context, the resolution of countering the negative effect of severe weather relies on urban planning from a meteorological perspective. Climate-sensitive architecture, as Fallmann and Emeis mentioned in their review, consists of all the techniques in the previous section, namely planted facades and roofs, highly reflective materials, etc. In the lens of the city, the economic, cultural, transportation, and political features are all taken into account [11]. The researchers believed that the preliminary planning of urban green and gardening should be under legislative provisions, which is agreed upon by Brian Shelton, marketing manager of Chief Buildings, Grand Island to involve as early as possible.

Climate-resilient "smart cities" should promote a coordinated effort. Selwin Hart, Special Adviser to the UN Secretary-General on Climate Action and Assistant Secretary-General for the Climate Action Team, noted that the extant institutions must be used to their best extent to avoid any further fragmentation in the process [12].

6 Conclusion

Only in the past 20 years, the meteorologists opened their arms to engineers and theorists from other fields of study, namely numerical weather forecasting. Severe weather events are causing a worldwide impact on the level of atmospheric, social, and architectural factors. Events like extreme rainfall, tropical cyclones, river flooding, and storm surge are related to frequent convection in high precipitation areas. This paper focused on the meteorological considerations in architectural design. It also reinforced the necessity to supply accuracy of severe precipitation forecasting and convey it effectively to architects. To solve the flooding problem, urban gardens such as green roofs/facades are introduced to many cities. On one hand, the interdisciplinary framework addresses certain construction materials that are heat, wind, or water-resistant, as well as some urban planning determinants. On the other hand, the natural resource degradation and natural disaster responses of the government may obscure the resilience of designed buildings. Still, the two major flaws in this article were undeniable: (1) the biases in source selection and (2) the lack of a well-reasoned framework in the conclusion. Due to the difficulty of obtaining industrial resources once the city is built, future generalizations of such innovative design during the early stages of urban construction are equally prospects and hazards. Additionally, the author expected more generalization of practiced cases and a more established global framework in the interdisciplinary field of sustainability and space.

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