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Traditional wisdom for disaster mitigation in history of Japanese Architectures and historic cities

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ABSTRACT

The objective of this paper is to reveal the reasons why the traditional buildings and cities have been able to survive the impacts of disasters in the long run that resulted in their heritage status. The study explains the new and old viewpoints on the cases of Japan with relation to the design of heritage buildings and historic cities that are sophisticated with traditional patterns, limited materials, and technologies of past, which is a kind of survival design for mitigation of unavoidable disasters. Recently, "disaster mitigation" has been looked upon to ward-off the unavoidable disasters within minimum damage as compared to "disaster prevention." Aiming at zeroing the damage, even the latest modern technology cannot completely undo the damages caused by the disasters, such as Kobe Earthquake in 1995 and 311 Tsunami in 2011. The present cultural heritages are associated with traditional wisdom, resulting in its survival from many disasters. This paper introduces the traditional Japanese towns and architectural buildings from the viewpoint of their resistance to disasters and sheds light on the "survival designs" that employ limited materials and available technologies. As per the context, the targeted natural disasters are divided into four parts, i.e., earthquake, city fire, flood, and others, including tsunami and windstorm. Aiming at these disasters and the risk they pose, a strong traditional knowledge base has to be gathered leading to the adoption of the disaster-mitigation methods in the modern architectural designs and further passing them on to the future generations.

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1. Introduction

The Japanese archipelago was formed as a result of the tectonic movements around the Pacific Rim. Thus, since its birth, the Japanese archipelago has endured frequent earthquakes, volcanic eruptions, and tsunami. Since steep mountains cover most of Japan's national territory, the country is constantly exposed to the risk of landslides and sediment disasters. In terms of climate, the Japanese archipelago is situated in the temperate monsoon zone and frequently suffers damage due to typhoons and heavy rainfall, particularly frequent floods due to steep rivers. Since people have managed to live in these extreme limited terrains of the islands, the population density of Japanese towns and cities is extremely high.

In addition, due to high precipitation, the mountains in Japan are covered with thick forests, providing abundant lumber. This has helped foster Japan's wood culture. The townsfolk living in densely populated cities use timber to build their houses, thus making the cities more vulnerable to fire. Hence, the Japanese archipelago is extremely susceptible to disasters of a broad variety, in a way that is unparallel to any other country in the world.

2. Research aims

There are important related researches on traditional measures for disaster mitigation in Japan. In case of Shaw's book (2014) [1], some types of traditional systems in such as Shirakawa village are revealed, and most cases are mainly explained as social intangible systems for disaster mitigation. And in the important report as "Indigenous Knowledge for Disaster Risk Reduction" (2008) [2], there is a concrete example on traditional knowledge for flood mitigation measure in the alluvial plain and delta area of the Gifu prefecture.

This paper tries to present various examples on physical tangible system from five different disaster types: earthquakes, fires, floods, tsunami and windstorm and focuses on the "lessons learnt from tradition to future". The purpose of this research is to collect and classify various types of physical characteristics as traditional knowledge for disaster mitigation in the history of Japanese architectures and historic cities. These characteristics should be referred

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to as important measures for the coexistence of conservation of cultural values and disaster mitigation toward future disasters.

In the case of serious disasters, even the modern infrastructures built for disaster prevention measures get damaged and do not work as expected. However, many of the historical architectures and cities have already survived the long history of disasters and became designated as cultural heritages because of this traditional wisdom. These traditional measures might not be able to prevent all the damages, but they can possibly act as effective mitigation measures when integrated with modern technologies.

3. Materials and methods

In this paper, various kinds of examples and related documents citing historical disaster-mitigation measures were collected and sorted in the order of each disaster type. The information on traditional characteristics for disaster-mitigation measures was divided into earthquake, fire, flood, tsunami and windstorm as discussed below.

3.1. Earthquake

The Japanese archipelago is located at the meeting point of four tectonic plates. The islands were formed by repeated crustal movements that eventually elevated parts of the seabed. Therefore, the country and its people are susceptible to earthquakes. In fact, 10–20% of all major earthquakes (over M6, during the last century) in the world have occurred in Japan, a country whose national territory accounts for only 0.25% of the entire land area on the planet. On an average, the Japanese archipelago has been hit by a large earthquake every 100 to 150 years.

3.1.1. *Reduction of shaking power;* five-storied pagodas

The five-story pagodas are unique in traditional Japanese architecture. The utmost priority in architectural design is focused on their height and not practical usability. Some pagodas use their interior space up to the second floor, but in any case, the upper floors remain unused. The sole aim of building pagodas was to protect the central pillar and make them tall for symbolism. As a result, the pagodas have overwhelming height as compared to their horizontal dimensions.

Historical reviews, however, have verified that no five-story pagodas have been destroyed by any earthquake. In a statistical study of the damage inflicted on 22 five-story pagodas built during and before the Edo Period (1603–1868), researchers showed that 12 of the pagodas underwent repair and renovation. According to the reports, those pagodas had endured a total of 16 earthquakes of seismic intensity 6 or higher (on the Japanese intensity scale). The damage inflicted by seven of those earthquakes was described in the reports, which revealed that none of the pagodas collapsed as a result of any earthquake, although a few of them tilted and the *sourin* (metal-work spire set on the top of a pagoda) of some others were damaged. [3] Despite the fact that many pagodas have been destroyed by typhoon winds or fires caused by lighting-strikes, no pagodas have ever been destroyed by an earthquake.

A five-story pagoda consists of one pillar penetrating from the bottom to the top of the structure. Except for this central pillar, the pillars of a pagoda support only one floor. The dimensions of a pagoda's floors differ, with the largest floor at the bottom and the smallest at the top. Accordingly, the supporting pillars of upper floors are placed closer to the central pillar. This tapering design gives an impression that the pagoda is taller than it actually is, adding elegance to its silhouette. (Fig. 1: left).

Beams of the individual floors are seldom connected to the central pillar. The five-story pagoda at *Horyu-ji* temple (World Cultural Heritage site) in Nara, which is the oldest extant pagoda in Japan, is made from a 2000-year-old Japanese cypress tree of more than 2.5 meter diameter. To avoid using distorted parts in the core, the cypress trunk was cut into four parts. The pillar was prepared with much meticulous care, and the beams of individual floors were not connected and fixed to the pillar.

To sum up, a five-story pagoda comprised of five independent structures of different dimensions; each structure was set on top of the story directly below. The five structures were loosely skewered by the central pillar. The vibrations from an earthquake are transmitted upward from the first to the second layer. The amplitude and period on each floor varied due to this structure, and the energy from the vibrations was naturally absorbed by friction, preventing a collapse. [4].

The center of the Tokyo Sky Tree, with a height of over 600 m, has a gap in its central concrete pillar. This central pillar includes parts that perform the same function as the oil damper in an automobile suspension. During an earthquake, it generates a different set of vibration and absorbs the energy, and its design prevents any structural collapse. (Fig. 1: right) Thus, in this case, we can learn from the earthquake-proof structure of the five-storied pagoda and apply it in the present as well as future infrastructures.

3.1.2. *Recovery from rocking;* Great Buddha Hall

Another issue was related to the restoration of the buildings to their original state after withstanding the vibrations. Recent research has clarified the thinking on "restorative capacity after being rocked." [5] This was the power at work that tried to restore the original state vis-à-vis the force when dominos started to fall. This force was further enhanced by making wider pillars and applying greater weight on them (Fig. 2).

The world's oldest timber-frame wooden main hall in existence is the *Daibutsu-den* (Great Buddha Hall) at the *Todai-ji* temple (World cultural heritage site) in Nara. It was first built in 758. It is a massive structure that is 60 m wide, 50 m long, and 45 m high, and has a heavy roof weighing 3020 tons. With as many as 84 pillars having a width 40 times greater than the requirement, the structure gains the ability to recover from the rocking, while having a grandness and elegance as a work of religious architecture.

3.1.3. *Non-fixed Basement;* Ishibatate

Ishiba-tate is also a traditional Japanese architectural method.

Basically, these are simple structures that have mounds of stones placed atop the foundation, but they are considered illegal under the present Building Standards Act. However, the construction method of "just laying them down" makes it difficult for a building to collapse since the earthquake's vibrations are diverted. [6] It has been theorized that this method was used for earthquake-proofing and for modern architecture (Fig. 3).

One example is the restored Former Imperial Audience Hall at the *Heijō-kyō* Palace in Nara, where the buildings were constructed with ancient architectural methods atop large trays with earthquake-resistant devices. By placing the earthquake-proof sliding-free equipments between the ground and the building, the strong vibrations can be reduced to a mere fraction. This is a technique contrived by modern people who learned from the wisdom of prior generations.

3.1.4. *Emergency exit door; earthquake*

An example of a contrivance created to preserve life by evacuating is the *kuguri-do no kagi* (wicket door locks) installed in basic traditional townhouses called *machiya*-style. These locks can be freely locked and unlocked from the inside and can be easily opened during an emergency, such as fire, but cannot be opened from the outside. In addition, it is a friction utilized design that will open on its own when a building is violently shaken by an earthquake, and

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