International Journal for Multidisciplinary Research (IJFMR)

E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

The Japanese Form of Construction

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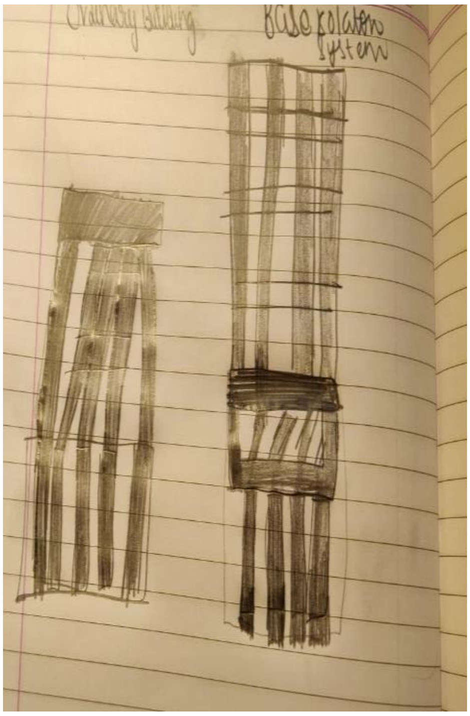
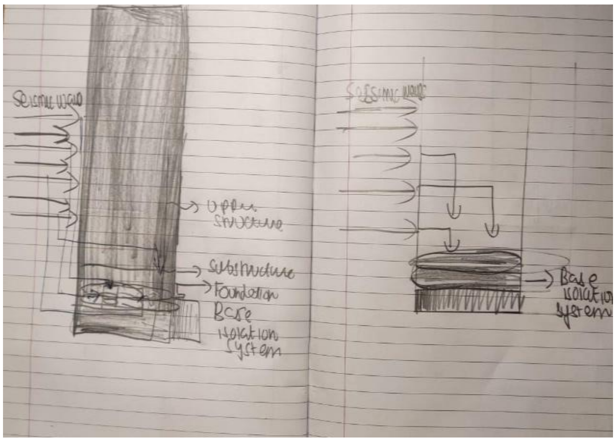
Abstract

The paper talks about the various methods used by Japan - an earthquake prone nation to minimize damage to life and infrastructure with a special emphasis on the transition within construction materials, scientific installations, surveys conducted by disaster management authorities. The paper also provides insights into future development and the possible loop holes within the existing system, while acknowledging that Japan still does have one of the best earthquake control systems in the world.



INTRODUCTION

Japan is one of the most earthquake prone countries in the world and has been a victim to 5-7 major earthquakes (magnitude 7 or higher) in the past 10-15 years. Though major quakes have been common currency since well before the 21st century, principals like base isolation system, damping system and seismic retrolifting have been dominant only since the past 2-4 decades. The base isolation system, which separates the base from the bottom structure or foundation (supported by rubber beams to prevent pressure generation at foundation) has been instrumental in preventing quakes, in accordance with the concept of inertia of motion. The motion of the sub structure is somewhat corresponding to that of the ground ,as a result of the force exerted on the earth due to the quake. The working of the system also depends on external factors such as the height, mass and materials used in construction of the building. This system is generally more beneficial for taller buildings as taller buildings tend to experience greater stress. Stress is defined as force per unit area (confined to solid materials) .Since area is relatively small for a higher structures , the force experienced is greater which makes the system a must in a elevated structure. Further it's imperative to say that a heavier structure is also subjected to higher force (since F=mass . acceleration) hence the same applies to such kind of a building. The given diagram contrasts how sessmic waves are transmitted in 2 building – one tall, heavy and one short, relatively lighter which have a base isolation system installed. It's visible that the taller structures system needs to absorb more energy and provide greater stability due to the increased forces caused by its height and mass distribution



BACKGROUND

Nearly 10% of the world's earthquakes occur in Japan, the first one traces back to the year 599, cuasing widespread damage throughout the Yamato Province. This trend only increased at an exponential rate from the 1828 earthquake to the great 1923 quake , Misawa quake of 1968, the 2011 tragedy and to the present 2024 disaster . Though earthquakes are increasing due to increased tectonic activity, human casualty and damage to infrastructure is decreasing at a rapid rate over the years. For instance earthquakes between 1900-1950 (magnitude between 6.5 to 8.5) resulted in thousands of deaths and widespread damage to property, The 2011 , 9.1 magnitude earthquake caused 122,000 houses and buildings to collapse(a large proportion of which were homes located in rural Japan). While the 1923's 8.5 magnitude quake resulted in 570,000 structures being knocked off . An important point to note is that out of the 122,000 structures (mostly houses)that collapsed due to the quake , most were destroyed due to the tsunami which occurred hours after the quake. Also in 2011, tens of millions of structures were registered as Japanese Property whereas in 1923 the number is as low as 3-4 million. Mathematically this means that around 0.2-1% of the structures collapsed as a consequence of the 2011 disaster whereas for 1923 , the percentage is as high as 20-25%.

Traditional Japanese Structures

These Structures are often made using wood which has some flexibility and is thus considerably earthquake proof. Another point to be observed is that even if a traditional structures collapsed , damage to life would be substantially lesser as compared to a modern building. These Structures consist of elements like sliding doors made of paper and wood, these light weight doors can flex during seismic activity. A post and beam construction method is followed where wooden beams are jointed together with mortise and tenon joints. To add to this most traditional buildings are low rise hence reducing risk of damage during an earthquake. These houses are designed to take advantage of natural ventilation and lighting with features such as large windows and open courtyards , thick walls and sliding doors help to regulate temperature, reducing the need for an artificial heating/cooling system. Use of materials like wood and bamboo creates a warm and inviting atmosphere.

Limitations of Traditional Japanese Structures

If the action of earthquakes is represented by a lateral force to act statically upon a rigid body at its centre of gravity, the resultant of the forces is shown in the diagram. In this case its fair to say that the rigid body would collapse regardless of its dimensions whenever the horizontal acceleration of

the ground motion exceeds a definite ratio to the acceleration of gravity. In the diagram attached below its visible that chances of destruction of the structure are substantially high. The horizontal component of the force (say Fcostheta, where theta= angle) can be added vectorially with the weight or force due to gravity .

i.e if mg>m.a (structure will collapse)

mg-Fcos theta=m.a

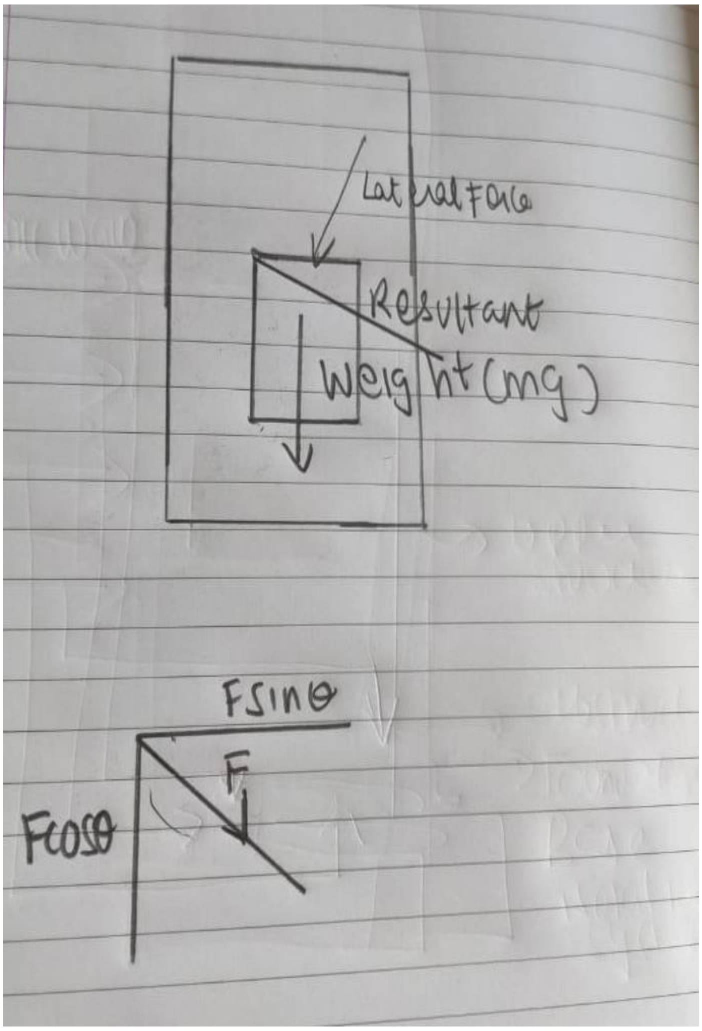
m(g-a)=fcos theta

Case 2

If m.a>mg(Structure will not collapse)

m.a=Fcos theta +m.g

m(a-g)= Fcos theta



The force on the structure due to the ground's motion is given by mass times acceleration or m.a . Whether or not the structure will stand tall depends on the difference in the scaler values of m.a and m.g where mg=weight , as explained in depth above.

Comparison With modern Structures

Clearly in case of modern structures , the base isolation system is designed to optimise inputs such as mass and acceleration as explained in detail initially. However, for traditional structures, the same does not hold true. Hence overall for high rise structures especially , a modern structure with all earthquake proof designs is a must , at the same time some traditional structures cant be destroyed due to lack of safety as they contribute significantly to Japanese Traditions and culture. Though whether or not these traditional houses should be used for living purposes or not could be an argument. However, the Japanese Government is encouraging dominance of modern structures , according to sources, the traditional Japanese buildings won't be a concept after 5 decades. They are being demolished to build modern structures.

Surveys

The Housing and land surveys being conducted over the years is an effective method used by the Statistics Bureau of Japan. Questionnaires are filled in the by the respondents which focusses on materials used for construction , housing conditions and impact of earthquakes on infrastructure. The reports are then analysed by the organisation and accordingly steps are taken to improve living conditions in Japan. However, this methodology has some limitations:

For instance,not all respondents have sufficient knowledge of technical aspects of building construction. Further statistical findings are only true on an average and hide disparities too. It's impossible to focus on each and every response filled in.

The need is to simplify the complexity of surveys. A sample questionnaire prepared by me is as follows:

Q1) Do you live in a traditional or modern structure

a) A traditional house (less than 5 storey)
b) Traditional building (more than 5 storey)
c) Modern house (less than 5 storey)
d) Modern house (more than 5 storey)
e) Other (please specify)

Q2) When was your property constructed ?

a) 10 years ago
b) More than 35 years ago
c) Less than 10 years ago
d) Around 20-30 years from now
e) Other (please specify)

Q3) What was the effect of earthquakes like on your property

A) Damage was substantial
B) Damage was negligible
C) The quake cause little to medium destruction ton the interiors such as the walls cracking up etc
D) Other (please specify)

Q4) Do you feel safe at your residence during an earthquake

a) Yes
b) NO
c) Somewhat safe
d) Not sure
e) None

Q5) Are you aware how earthquake resilient your house is

A) Yes (please elaborate)
B) No
C) Unsure (please explain)

D) other(specify)

Q6) Has your building/ residence under gone any earthquake proof inspection?

A) Yes (please mention how frequently its done)
B) No
C) Not aware

Q7) What aspect do you think should be looked into as far as safety of life and property is concerned during earthquakes?

If the bureau uses such type of surveys rather than including questions about the type of concrete and what proportion of mixture of cement is used in construction, The results will be more authentic .Though some straightforward questions are also present, technical questions do contribute to giving misleading results keeping in mind a common person is filling in the questionnaire

MISCONCEPTIONS ABOUT JAPANESE BUILDINGS

1. All Japanese structures are earthquake proof. As explained above traditional structures are not nearly as earthquake resilient to stand quakes of magnitude 7 and above
2. Earthquake proof buildings don't require additional safety measures. Though new technologies play a significant role in curbing quake destruction, regular inspections by bodies like Fire and Disaster Management Agency (FDMA) are a need. Materials used in construction may deteriorate over time and regular repairs are thus a must.
3. All earthquake proof buildings use the same technology. There are different levels of earthquake resistance, not all structures use a particular technique and same may follow a combination of techniques such as base isolation system and damping system while others may employ seismic retrolifting.

Hence the need is to educate citizens about the type of structure they are living in. They must be aware of its components, age of building, whether or not safety inspections are being held.

Differences between earthquake proof technologies

MECHANISM - As explained in depth a base isolator prevents a structure to move and follow the ground as it sways while a seismic damper absorbs the quake waves and thus reduces the effect of destruction

PLACE OF INSTALLATION On one end a base isolation system can only be installed at the foundation connecting to the sub structure using rubber bearings , a damping system can be installed anywhere with the structure depending on external factors

IMPACT/ METHDOLOGY - Base isolation system is aimed at reducing the effect of applied force due to the quake while damping system reduces vibrations /treamors by improving structural strength and flexibility .

Materials used in construction of Modern Buildings

Reinforced concrete has been a dominant element in construction of modern Japanese structures , promoted by Professor Toshikata (Riki) Sano of the University of Tokyo in the 1920's after investigation of damages from the San Fransico Earthquake of 1906. He noted the good performance of such structures against earthquakes.

When Tokyo was hit by an 8.0 magnitude earthquake in 1923, 80% of reinforced concrete structures stood tall whereas 20% suffered significant to substantial damage , Most structures which collapsed were the brick dominant ones or poor foundation / irregular configuration buildings . At the time earthquake proof methodologies were not common currency. It can be inferred that reinforced concrete structures with earthquake resilience methods are designed to stand high magnitude earthquakes.

HIGH STRENGTH CONCRETE

A type of concrete with a compressive strength substantially higher than conventional concrete . Typically used in projects where durability is required such as high rise buildings .It is a dominant concept amongst

modern Japanese Buildings
Due to its dense composition and lower porosity , high strength concrete offers improved resistance to environmental factors like moisture chloride penetration and chemical attacks. This durability is achieved by a low water to cement ratio and additional mixtures.
Thus The material enables engineers to design taller structures. It can support a greater load as it has a comprehensive strength of 40mPa, considered phenomenally high.
However This comes with some limitations such as high cost of construction, complex mix design-preparing it requires a precise measure of water cement and other elements . High strength concrete is more brittle than convential concrete , subjecting it to deforms.
However for tall buildings , it's generally considered an ideal material

MATERIALS USED (BETWEEN 1900-2000)
Typically wood and steel were popular, traditional landscape and temples were popular in the first half the century after which concrete and other advanced forms of it took control.
Between 1800-1900
Bamboo , paper and wood were the most commonly used elements in contruction. On one end wood was strong enough to hold the structure and on the other end the flexibility and light weight of paper and bamboo added to the adaptability of wood during seismic events .
Between 1600-1800
Stone was a very popular construction tool , used in castle walls and even foundations. In rural Japan houses were supported by a combination of stone and mud until 1650, after which wood and mud brick gained popularity. However most of these materials were'nt earthquake proof and had less flexibility.
Before 1500
Thatch roofs were a common trend made from reed , straw or other plant materials . Clearly it was a natural and renewable technique of construction. The material possessed weather Resistant properties, providing protection against sun, wind and the rain.

CONCLUSION
Overall it's fair to conclude that Japanese architects and engineers have recognised the fact that Japan lies in a seismically active zone, buildings are designed accordingly. However though building codes and designing laws are strict in Japan , it is unsure whether or not there's much stress on regular surveys and investigations . There's also partial and not full clarity in the statistics basis questionnaire's filled in by residents as a part of the questions are much too advanced from a citizens perspective . Although the finest of materials are used for construction, this is not a guarantee to safety. Certain Construction materials may deteriorate over time, while some materials may weaken other's may undergo rusting. Residents must be aware of such things and seek help from the relevant organisations in case of such scenario's. While traditional architecture is no longer a popular concept due to lack of earthquake resilient methodologies , the structures can be used only for cultural importance rather than for living purposes, further the buildings incorporate principals like sustainable architecture – a principal incorporated into modern structures too.

FUTURE INSIGHT
In the future there will be a greater tilt towards green architecture by encouraging net zero buildings to reduce carbon emissions and thus conserve energy. Concepts like rapid response and early warning system

will be common. Use of artificial intelligence for maintenance and enhanced security features is the talk of the hour. Speaking of the present to end things on a positive note, the country and its government have learned from past earthquakes and the irreparable damage caused by the same (BEFORE 1900) and then invested accordingly into building safety measures leading to earthquake proof buildings soon after.

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