iJournals: International Journal of Software & Hardware Research in Engineering (IJSHRE)
ISSN-2347-4890
Volume 10 Issue 5 May 2022

Novel Approach to Analyse Structures to Predict Earthquake Impact in Urban Areas

Meet Modi
Hiranandani Foundation School
Hiranandani Gardens, Powai, Mumbai

Reetu Jain
Chief Mentor
On My Own Technology Pvt Ltd, Mumbai, India

Abstract

In recent decades, earthquake disaster risks in cities have increased due to a high rate of urbanisation, faulty land-use planning and construction, inadequate infrastructure services, and environmental degradation. Thus, for urban centres under possible exposure to earthquakes, it is imperative that certain preparedness and emergency procedures be contrived in the event of and prior to an earthquake, which in turn requires quantification of the effects of the earthquake on the environment. The main element of such quantification is the building losses, which is correlated to casualties, planning of emergency response, first aid and emergency shelter needs. Recent earthquakes show how significant urban earthquake disaster prevention planning is. This is where my project comes in and it aims to assist in city planning and reduce the risk of an unprecedented disaster. My project is to predict and calculate the earthquake impact in Urban areas by analysing the building structures in the particular area. In our algorithm, we have taken images of buildings from google maps as inputs. Just from that, our software is able to calculate dimensions of the building like volume, height, and safe area, which is the area of damage caused by the debris of the building.We used very efficient methods of image processing and Machine Learning models, to go further, and even predict the effect of seismic waves with different intensities on the particular inputs. This can indicate the appropriate distance between several buildings in order to decrease the risk. We mapped the safe area in a city as gradients to indicate the peril during such a calamity.Our unparalleled model was able to achieve high levels of accuracy even with 20 trials due to the mathematical models. This software and algorithm could, in the future, also be implemented to other structures with various shapes, like bridges and stadiums, which will essentially help us collect data from all around the world and help with infrastructure development.

Keywords: *Earthquake Impact,Natural calamities, Urban settlements, Machine Learning, Image Processing, Damage prediction, Building Structures and strength.*

Introduction

As simply defined by National Aeronautics and Space Administration (NASA), an earthquake is an intense shaking of the Earth’s surface which is caused by movements in Earth’s outermost layer. An earthquake is caused by a sudden slip on a fault. The tectonic plates are always slowly moving, but they get stuck at their edges due to friction. When the stress on the edge overcomes the friction, there is an earthquake. To put it more technically, there is a sudden release of strain energy, which spreads out in all directions like ripples on a pond, in the Earth’s crust, resulting in waves of shaking that radiate outwards from the earthquake’s initial point of rupture, which is termed the focus or hypocentre. The surface directly above the hypocenter is called the epicentre. As this vibrational energy is dissipated, we experience the tremor known as earthquake.

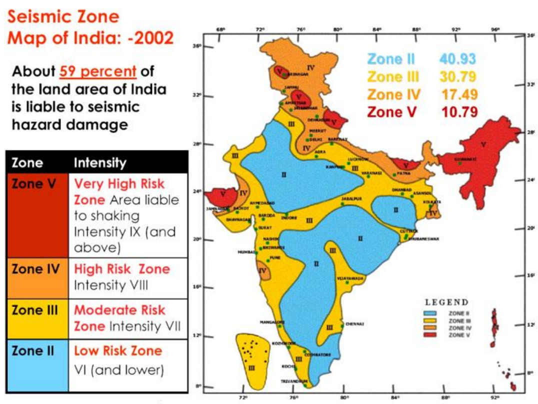


Fig. 1 Seismic zonation and intensity map of India

How it's measured

To make a record of such seismic waves caused by an earthquake, we use an instrument called a seismograph or seismometer. These seismographs are furnished with electromagnetic sensors that translate ground motions of these earthquakes into electrical changes, which are processed and recorded by the instruments' analog or digital circuits. There are a number of ways to understand the readings shown on the seismograph. The first widely-used method, the Richter scale , was developed by U.S. seismologist Charles F. Richter in 1934. It used a formula based on the amplitude of the largest wave recorded and the distance between the earthquake and the seismometer. The scale is logarithmic (as shown in *fig. 1)*, so that each increase of one unit represents a 10-fold increase in magnitude.

Richter Scale	Mercalli Intensity	Shaking	Description/Damage
1.0 - 3.0	I	Not felt	Not felt except by a very few under especially favorable conditions.
3.0 - 3.9	II	Weak	Felt only by a few persons at rest,especially on upper floors of buildings.
	III	Weak	Felt quite noticeably by persons indoors, especially on upper floors of buildings. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.
4.0 - 4.9	IV	Light	Felt indoors by many, outdoors by few. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.
	V	Moderate	Felt by nearly everyone. Some windows broken. Unstable objects overturned.
5.0 - 5.9	VI	Strong	Felt by all. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
	VII	Very strong	Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures.
6.0 - 6.9	VIII	Severe	Damage slight in specially designed structures; considerable damage in ordinary buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, monuments, walls.
	IX	Violent	Damage considerable in specially designed structures. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
7.0 and higher	X	Extreme	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.
	XI	Extreme	Few, if any (masonry) structures remain standing. Bridges destroyed. Rails bent greatly.
	XII	Extreme	Total damage. Lines of sight and level are distorted. Objects thrown into the air.

[Fig 1]

Unfortunately, many scales, such as the Richter scale, do not provide accurate estimates for large magnitude earthquakes. Today, the intensity of earthquakes is most commonly measured through the Mercalli Intensity Scale, developed in 1884 and modified in 1931. The Modified Mercalli Intensity Scale is divided into 12 degrees (by Roman numeral), and while these degrees generally correspond to magnitudes on the Richter scale, they can vary depending on how people and structures react to shaking. The Modified Mercalli Scale (MM) reflects the observed effects caused by earthquakes, as opposed to its overall magnitude as conveyed by the Richter scale.

Effects

According to the World Health Organisation, Between 1998-2017, earthquakes caused nearly 7,50,000 deaths globally, more than half of all deaths related to natural disasters. More than 125 million people were affected by earthquakes during this time period, meaning they were injured, made homeless, displaced or evacuated during the emergency phase of this disaster.

Due to the rapid rate of urbanisation across places around the world, it is conspicuous that the effect of earthquakes has the most impact on cities which are unofficially called concrete jungles. For example, California in the United States of America (USA), when the Great San Francisco Quake of 1906 occurred, it was recorded to have a magnitude of 7.9 on the richter scale, which falls in the major category, and it caused massive destruction due to seismic shaking, subsequent fires, and tsunami action. It caused $500 million USD in damage – the equivalent of more than $13 billion USD in recent times.

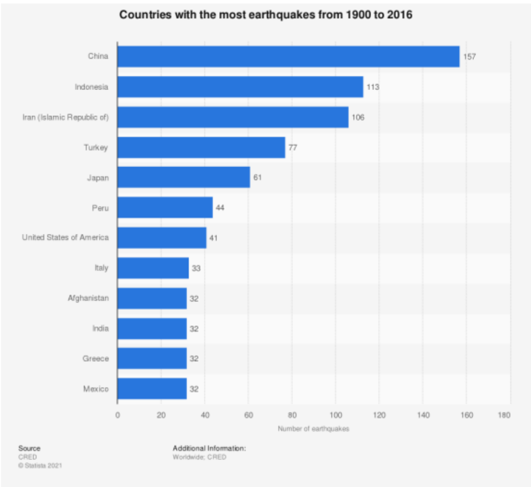
India on account of its unique geo-physical setting is highly prone to earthquakes of varying intensities. The country has faced several devastating earthquakes in the past resulting in a large number of deaths and severe property damage. During the last century, five earthquakes measuring M8 or more had struck different parts of the country; Great Assam earthquake (1897), Kangra earthquake (1905), Bihar-Nepal earthquake (1934), Andaman-Nicobar earthquake (1941) and Assam earthquake (1950) had caused untold misery to the affected community and enormous damage to infrastructure and public and private property.

The National Oceanic and Atmospheric Administration (NOAA) reports there were 195 earthquakes of magnitude 5.5 or greater in developed countries from 1985 to 2015. Of these 195 large quakes, the NOAA lists economic damage estimates for about a quarter of them as damage estimates are more available for earthquakes that occur in highly populated areas.

*i*Journals: International Journal of Software & Hardware Research in Engineering (IJSHRE)
ISSN-2347-4890
Volume 10 Issue 5 May 2022

Date	Area	Magnitude	Mercalli Intensity	Local Population	Damage ($mil, 2015 dollars)
March 11, 2011	Japan: Honshu (main island)	9.0	n/a	103,900,000	$231,806
September 25, 2003	Japan: Hokkaido	8.3	n/a	5,627,737	$116
November 3, 2002	Alaska: Slana, Mentasta Lake, Fairbanks	7.9	9	124	$74
December 28, 1994	Japan: Honshu (main island)	7.8	9	100,751,000	$272
July 12, 1993	Japan: Hokkaido; Russia: Southeast; South Korea	7.7	8	5,692,321	$1,980
January 15, 1993	Japan: Hokkaido, Kushiro, Hachinohe, Honshu	7.6	6	106,151,000	$587
June 28, 1992	California: Landers, Yucca Valley	7.6	9	17,090	$155
April 25, 1992	California: Humboldt County: Ferndale, Petrolia	7.1	8	123,032	$127
September 3, 2010	New Zealand: Christchurch	7.0	9	376,700	$7,064
May 26, 2003	Japan: Honshu: Iwate, Miyagi, Yamagata, Akita	7.0	n/a	6,165,000	$300
January 16, 1995	Japan: SW Honshu: Kobe, Awaji-Shima, Nishinomiya	6.9	11	1,931,505	$155,529
October 18, 1989	California: Loma Prieta	6.9	9	581,335	$10,708
February 28, 2001	Washington: Olypia, Seattle, Tacoma	6.8	8	809,244	$2,677
March 24, 2001	Japan: Hiroshima, Okayama, Honshu, Kagama	6.8	9	1,855,415	$669
January 17, 1994	California: Northridge	6.7	9	1,400,000	$63,957
October 6, 2000	Japan: Honshu: W: Okayama, Tottori	6.7	9	777,081	$206
October 15, 2006	Hawaiian Islands	6.7	8	169,540	$86
October 23, 2004	Japan: Honshu: Niigata Prefecture	6.6	n/a	2,445,000	$35,128
July 16, 2007	Japan: Honshu: W Coast	6.6	n/a	2,408,000	$14,288
May 13, 1995	Greece: Grevena-Kozani, Thessaloniki, Yugoslavia	6.6	8	385,406	$700
March 2, 1987	New Zealand: North Island, Whakatani, Edgecumbe	6.6	10	257,379	$438
December 22, 2003	California: Paso Robles, Templeton, Atascadero	6.6	8	254,240	$386
June 15, 1995	Greece: Aiyion, Eratini	6.5	7	97,785	$1,026
June 17, 2000	Iceland: Vestmannaeyjar, Hella	6.5	n/a	112,960	$28
January 10, 2010	California: Off Northern Coast	6.5	n/a	135,022	$24
June 21, 2000	Iceland: Grimsnes, Selfoss, Eyrarbakki, Stokkseyri	6.5	n/a	112,960	$17
April 6, 2009	Italy: L'Aquila	6.3	n/a	298,343	$2,761
November 24, 1987	California: Superstition Hills	6.2	6	100,077	$6
July 21, 1986	California-Nevada: Chalfant Valley	6.2	6	8,795	$2
February 21, 2011	New Zealand: Christchurch, Lyttelton	6.1	n/a	376,700	$15,805
January 26, 2014	Greece: Kefalonia	6.1	n/a	35,801	$178
September 26, 1997	Italy: Central: Marche, Umbria	6.0	10	2,279,050	$6,681
September 7, 1999	Greece: Athens	6.0	9	789,166	$5,975
June 13, 2011	New Zealand: South Island: Canterbury	6.0	n/a	539,436	$3,161
August 24, 2014	California: Napa, Vallejo	6.0	n/a	200,239	$701
September 6, 2002	Italy: Sicily: Palermo	6.0	n/a	686,722	$659
September 21, 1993	Oregon: Klamath Falls	6.0	7	18,105	$12
December 17, 1987	Japan: Honshu: Chiba Perfecture, Tokyo	6.0	8	17,194,000	$10
July 8, 1986	California: Palm Springs	6.0	7	41,132	$10
May 29, 2012	Italy: Emilia Romagna: Medolla, Mirandola, Cavezzo	5.9	n/a	4,300,000	$16,309
September 13, 1986	Greece: Kalami, Lakonia, Zakinthos	5.8	10	163,992	$11
July 13, 1986	California: San Diego, Newport Beach	5.8	6	1,100,000	$2
October 31, 2002	Italy: San Guiliano Di Puglia, Campobasso	5.7	n/a	320,143	$1,049
October 1, 1987	California: Whittier	5.7	8	77,867	$747
March 25, 1993	Washington-Oregon Border	5.6	7	249,287	$47
July 25, 2003	Japan: Honshu: Miyahi, Iwate	5.5	n/a	3,770,000	$529
February 28, 1990	California: S, Claremont, Covina	5.5	7	76,380	$23
December 26, 1994	California: Eureka, Samoa, Aracata, Blue Lake	5.5	7	43,373	$3
	Simple correlation with damage	***0.43***	***0.46***	***0.42***	

Earthquakes in developed countries	Average damage ($mil, 2015 dollars)	Median damage ($mil, 2015 dollars)
All 5.5+ quakes	$12,146	$484
Magnitude > 6.5	*$23,966*	*$628*
Magnitude 5.5 to 6.5	*$2,145*	*$178*
Population > 250,000	*$20,705*	*$1,980*
Population < 250,000	*$172*	*$28*



The socio-economic vulnerability of an urban system also needs to be assessed in terms of casualties, social disruption and economic loss for a comprehensive earthquake damage and loss scenario. Casualties in earthquakes arise mostly from structural collapses and from collateral hazards. Lethality per collapsed building for a given class of buildings can be estimated by the combination of factors representing the population per building, occupancy at the time of the earthquake, occupants trapped by collapse, mortality at collapse and mortality post-collapse.

While buildings may perform adequately under strong shaking, the performance of interior systems also is important. Damage to nonstructural systems in buildings can represent economic losses and can require significant repair times to bring the building back into operation. Thus, these systems also must perform adequately to meet the intended performance of the building as a whole both during the event and after.

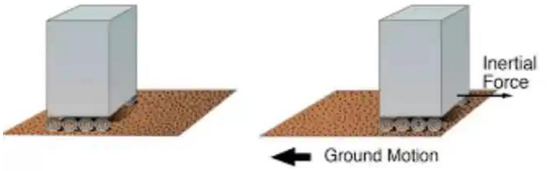
Knowledge of the performance of soils under strong ground shaking remains an area of needed research.

What are the Effects of Earthquake on Structures?

1. Inertia Forces in Structures

The generation of inertia forces in a structure is one of the seismic influences that detrimentally affect the structure. When an earthquake causes ground shaking, the base of the building would move but the roof would be at rest. However, since the walls and columns are attached to it, the roof is dragged with the base of the building.

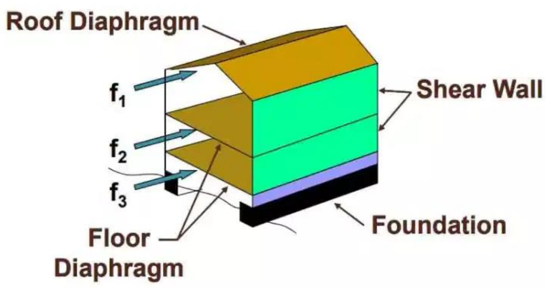
The tendency of the roof structure to remain at its original position is called inertia. The inertia forces can cause shearing of the structure which can concentrate stresses on the weak walls or joints in the structure resulting in failure or perhaps total collapse. Finally, more mass means higher inertia force that is why lighter buildings sustain the earthquake shaking better.



2. Effect of Deformations in Structures

When a building experiences an earthquake and ground shaking occurs, the base of the building moves with the ground shaking. However, the roof movement would be different from that of the base of the structure. This difference in the movement creates internal forces in columns which tend to return the column to its original position.

These internal forces are termed stiffness forces. The stiffness forces would be higher as the size of columns gets higher. The stiffness force in a column is the column stiffness times the relative displacement between its ends.

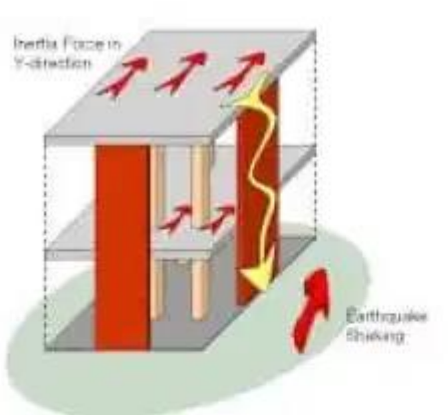


3. Horizontal and Vertical Shaking

Earthquakes cause shaking of the ground in all the three directions X, Y and Z, and the ground shakes randomly back and forth along each of these axis directions. Commonly, structures are designed to withstand vertical loads, so the vertical shaking due to earthquakes (either adds or subtracts vertical loads) is tackled through safety factors used in the design to support vertical loads.

However, horizontal shaking along X and Y directions is critical for the performance of the structure since it generates inertia forces and lateral displacement and hence adequate load transfer path shall be provided to prevent its detrimental influences on the structure.

Proper inertia force transfer path can be created through adequate design of floor slab, walls or columns, and connections between these structural elements. It is worth mentioning that the walls and columns are critical structural members in transferring the inertial forces. It is demonstrated that masonry walls and thin reinforced concrete columns would create weak points in the inertia force transfer path.



Literature Review

India is one of the most disaster prone countries, vulnerable to almost all natural and man made disasters. About 85% of the area is vulnerable to one or multiple disasters and about 57% of the area is in a high seismic zone including the capital of the country. Disaster prevention involves engineering intervention in buildings and structures to make them strong enough to withstand the impact of natural hazard or to impose restrictions on land use so that the exposure of the society to the hazard situation is avoided or minimised.

IS 13920:1993 Ductile Detailing of Reinforced Concrete Structures Subjected to Seismic Forces – Code of Practice

This standard covers the requirements for designing and detailing of monolithic reinforced concrete buildings so as to give them adequate toughness and ductility to resist severe earthquake shocks without collapse.

IS 13828:1993 Improving Earthquake Resistance of Low Strength Masonry Buildings – Guidelines

This standard covers the special features of design and construction for improving earthquake resistance of buildings of low-strength masonry.

The provisions of this standard are applicable in all seismic zones. No special provisions are considered necessary for buildings in seismic zone II if cement-sand mortar not leaner than 1:6 is used in masonry and through stones or bonding elements are used in stone walls.

IS 13827:1993 Improving Earthquake Resistance of Earthen Buildings – Guidelines

The guidelines covered in this standard deal with the design and construction aspects for improving earthquake resistance of earthen houses, without the use of stabilisers such as lime, cement, asphalt, etc.

IS 4326:1993 Earthquake Resistant Design and Construction of Buildings - Code of Practice

This standard provides guidance in selection of materials, special features of design and construction for earthquake resistant buildings including masonry construction, timber

*i*Journals: International Journal of Software & Hardware Research in Engineering (IJSHRE)
ISSN-2347-4890
Volume 10 Issue 5 May 2022

construction, prefabricated construction etc. In this standard, it is intended to cover the specified features of design and construction for earthquake resistance of buildings of conventional types. The general principles to be observed in the construction of such earthquake resistant buildings as specified in this standard are Lightness, Continuity of Construction, avoiding/reinforcing Projecting and suspended parts, Building configuration, strength in various directions, stable foundations, Ductility of structure, Connection to non-structural parts and fire safety of structures.

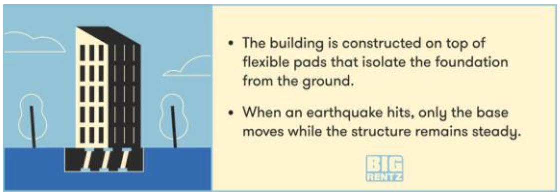
.

IS 1893:1984 Criteria for Earthquake Resistant Design of Structures

Consequent to the publication of this standard on account of earthquakes in various parts of the country including that in Uttar-Kashi, Latur and Bhuj and technological advancement in the field, the Sectional Committee decided to revise the standard into five parts which deals with different types of structures:

Part 1 : General provisions and Buildings
Part 2 : Liquid Retaining Tanks – Elevated and Ground Supported
Part 3 : Bridges and Retaining Walls
Part 4 : Industrial Structures Including Stack Like Structures
Part 5 : Dams and Embankments

1. **Create a Flexible Foundation**



One way to resist ground forces is to "lift" the building's foundation above the earth. Base isolation involves constructing a building on top of flexible pads made of steel, rubber, and lead. When the base moves during the earthquake, the isolators vibrate while the structure itself remains steady. This effectively helps to absorb seismic waves and prevent them from travelling through a building.

2. **Vibrational Control Devices**

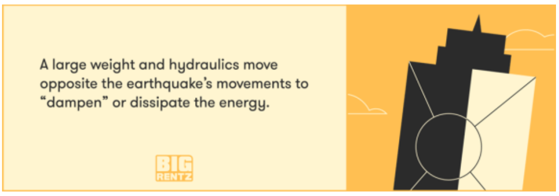
Counter Forces with Damping

You might be aware that cars have shock absorbers. However, you might not know that engineers also use them for making earthquake-resistant buildings. Similar to their use in cars, shock absorbers reduce the magnitude of shockwaves and help buildings slow down. This is accomplished in two ways: vibrational control devices and pendulum dampers.

Vibrational Control Devices

The first method involves placing dampers at each level of a building between a column and beam. Each damper consists of piston heads inside a cylinder filled with silicone oil. When an earthquake occurs, the building transfers the vibration energy into the pistons, pushing against the oil. The energy is transformed into heat, dissipating the force of the vibrations.

Pendulum Power



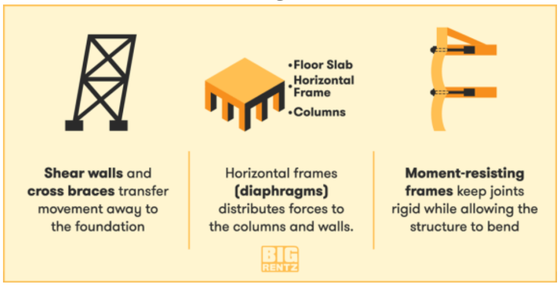
Another damping method is pendulum power, used primarily in skyscrapers. Engineers suspend a large ball with steel cables with a system of hydraulics at the top of the building. When the building begins to sway, the ball acts as a pendulum and moves in the opposite direction to stabilise the direction. Like damping, these features are tuned to match and counteract the building's frequency in the event of an earthquake.

3. **Shield Buildings from Vibrations**

Instead of just counteracting forces, researchers are experimenting with ways buildings can deflect and reroute the energy from earthquakes altogether. Dubbed the "seismic invisibility cloak", this innovation involves creating a cloak of 100 concentric plastic and concrete rings and burying it at least three feet beneath the foundation of the building.

As seismic waves enter the rings, they are forced to move through to the outer rings for easier travel. As a result, they are essentially channelled away from the building and dissipated into the plates in the ground.

4. Reinforce the Building's Structure



To withstand collapse, buildings need to redistribute the forces that travel through them during a seismic event. Shear walls, cross braces, diaphragms, and moment-resisting frames are central to reinforcing a building.

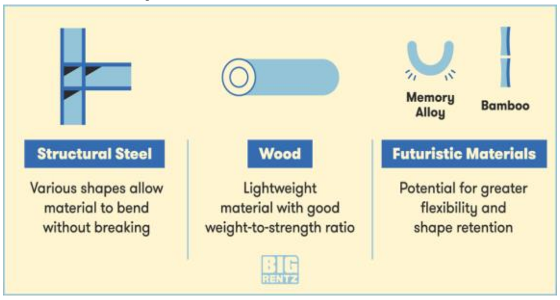
Shear walls are a useful building technology that helps to transfer earthquake forces. Made of panels, these walls help a building keep its shape during movement. Shear walls are often supported by diagonal cross braces. These steel beams have the ability to support compression and tension, which helps to counteract the pressure and push forces back to the foundation.

Diaphragms are a central part of a building's structure. Consisting of the floors of the building, the roof, and the decks placed over them, diaphragms help remove tension from the floor and push force to the vertical structures of the building.

Moment-resisting frames provide more flexibility in a building's design. This structure is placed among the joints of the building and allows for the columns and beams to bend while the joints remain rigid. Thus, the building is able to resist the larger forces of an earthquake while allowing designers more freedom to arrange building elements.

Earthquake-Resistant Materials

While shock absorbers, pendulums, and "invisibility cloaks" may help dispel the energy to an extent, the materials used in a building are equally responsible for its stability.



Steel and Wood

For a building material to resist stress and vibration, it must have high ductility — the ability to undergo large deformations and tension. Modern buildings are often constructed with structural steel — a component of steel that comes in a variety of shapes that allow buildings to bend without breaking. Wood is also a surprising ductile material due to its high strength relative to its lightweight structure.

Innovative Materials

Scientists and engineers are developing new building materials with even greater shape retention. Innovations like shape memory alloys have the ability to both endure heavy strain and revert to their original shape, while fibre-reinforced plastic wrap — made by a variety of polymers — can be wrapped around columns and provide up to 38% greater strength and ductility.

Engineers are also turning to natural elements. The sticky yet rigid fibres of mussels and the strength-to-size ratio of spider silk have promising capabilities in creating structures. Bamboo and 3D printed materials can also function as lightweight, interlocking structures with limitless forms that can potentially provide even greater resistance for buildings.

Over the years, engineers and scientists have devised techniques to create some effective earthquake-proof buildings. As advanced the technology and materials are today, it is not yet possible for buildings to completely withstand a powerful earthquake unscathed. Still, if a building is able to allow its occupants to escape without collapsing and saves lives and communities, we can consider that a great success.

Our Solution

Our algorithm is a novel and practical solution that can be used to calculate the magnitude and scope of damage that is ensued by earthquakes. We researched the different factors that are considered when an architectural structure is being built, such as height, surface area, and volume to measure the damage caused by a seismic wave. Architects believe that these are the main components that go into making an earthquake-resistant building, hence we believe that further analysing them will showcase the effects of seismic waves on buildings accurately. This project delves into an untapped territory of correlating architecture with machine learning. We were able to identify factors like soil composition beneath the building, volume and the crumble zone to be major contributors.

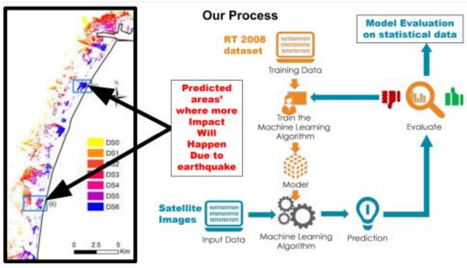
In our present algorithm, we have taken images of buildings from google maps as inputs. Just from that, our software is able to calculate dimensions of the building like volume, height, and safe area, which is the area of damage caused by the debris of the building. Previous methods used to detect earthquakes were inefficient as seismic experts had to visually examine recorded data. We however used more efficient methods of image processing and Machine Learning models, to go further, and even predict the effect of seismic waves with different intensities on the particular inputs. This can indicate the appropriate distance between several buildings in order to decrease the risk. We mapped the safe area in a city as gradients to indicate the peril during such a calamity.

```
def shoelace(X, Y, n):
    area = 0.0
    j = n - 1
    for i in range(0,n):
        area += (X[j] + X[i]) * (Y[j] - Y[i])
        j = i
    #vertices = len(X)
    #print(shoelace(X, Y, vertices))
    return abs((area / 2.0)/24)#constant for zoom value 20 is 24
```

This shoelace technique is a mathematical algorithm which constantly cross-multiplies corresponding coordinates of the different vertices of a polygon to determine the area of a simple irregular polygon. We have implemented this method in our software which makes it unchallenging to find the area of the top view of the building.

In our software, we have also created multiple functions that gather all the necessary information when the user interacts with our software. For example, the get_length() function calculates the height of a building along a constant (that we found from the using the known height of the Burj Khalifa). With area and height in place, finding the volume was effortless for our software and the user is provided with an estimated volume as well. With our innovation, we are able to map a building's crumble zone on the image and check if it overlaps with any other building's crumble zone in the same locality. This helps us understand the possibility of a "domino effect" of buildings. This can also help town planners to build buildings well outside the crumble zone of another building nearby and prevent mishap.

To use our algorithm, the user will require access to Google Maps, as the inputs fed into our software are in the form of satellite pictures of buildings taken from the application. The user will then be able to interact with the output, as they should tap the vertices on the roof of the building that helps the algorithm to calculate the dimensions. After selecting all the vertices, the algorithm extracts a polygonal figure, which is the outline of the input. Here, it implements the aforementioned *Shoelace Technique*. To help the user understand the working of our software, we have used a black output screen that displays all the calculations made. The software has been coded in such a way that specific keywords help the user calculate the different dimensions of the building. The keyword "a" will automatically calculate the area the building covers using the shoelace formula. The keyword "h" will find the height of the particular building using the get_length() function along with the shadow of the building. One of the more advanced functions in our software is the one that displays the safe area around the building. The keyword to find this out is "q."

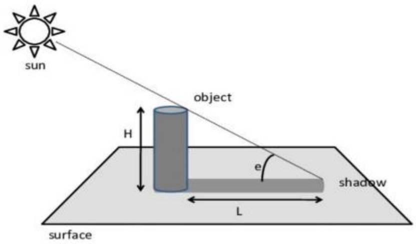


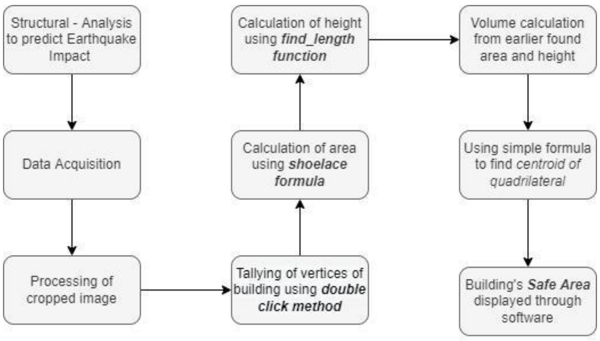
Due to our software, we were also able to infer how seismic waves travel faster through hard rock than soft soil and the stiffness of the building is proportional to its volume. We used a custom 2008 RT data set for trials and calculated the accuracy of our software which runs on Python Programming. To test our model, we took the average of the calculations we received after 20 data trials. The 4 main dimensions we calculated were surface area, building height, building volume, and safe area around the building.

The accuracies we got from the 20 trials are:
Surface Area- 99.3854% accurate
Building Height- 99.4929% accurate

Building Volume- 99.5402% accurate
Safe Area- 99.6054% accurate

Our unparalleled model was able to achieve high levels of accuracy even with 20 trials due to the mathematical models we implemented when defining the functions. The algorithm is very easy to use due to the keywords we have defined. Our algorithms are the core of the project that enable smart governance at city and suburb level to gauge the impact. After teaching our software through constant data feeding, we will soon be able to map clusters of spaces in various cities and find areas with the most risk. This will help curve economic costs as well as prevent life loss. We continue to further study the volume of the building, correlate it with the mass and centre of gravity and predict the angle and the direction of the tilt.





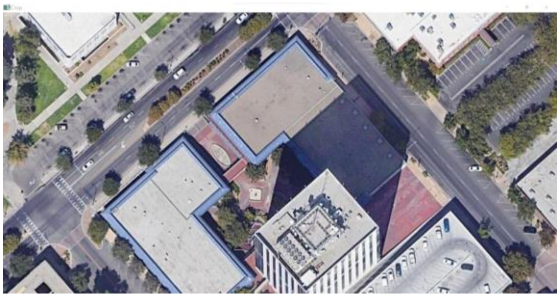

```
def getlineLength(pt1,pt2):
    length = round(m.sqrt((pt2[0] - pt1[0])**2+(pt2[1]-pt1[1])**2))
    return length
```

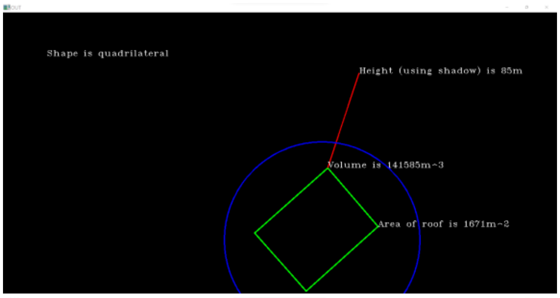
```
def draw_circle(event,x,y,flags,param):
    if event==cv.EVENT_LBUTTONDBLCLK:
        pts.append([x,y])
        X.append(x)
        Y.append(y)
        print(x,y)
        cv.circle(img,(x+thr,y+thr),5,(255,0,0),-1)
```

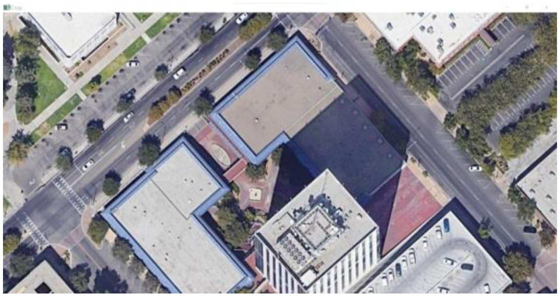
```
def findlength(img2, pts, color):
    for x in range(len(pts)):
        if (x >= (len(pts) -1)):
            l = getlineLength(pts[x],pts[0])
        else:
            l = getlineLength(pts[x],pts[x+1])
        print(l)
        area_length.append(round(l))
```

```
findlength(img2, pts, (0,0,255))
h=area_length[0]
print("height is",area_length[0]*0.375,"m")
cv.putText(img2, 'Height (using shadow) is '+str(round(area_length[0]*0.375))+'m',pts[1],5,1,(255,255,255),1 ,2)
cv.imshow("OUT",img2)
# put function to find height and volume
#constant of 0.375 for zoom value 20
vol=area_length[0]*0.375*areaabs
print("volume is",round(vol),"m^3")
mass= vol*2400 #2400 is the density of normal concrete in kg/m^3
print("mass of structure is", round(mass),"kg")
cv.putText(img2, 'Volume is '+str(round(vol))+'m^3',pts[0],5,1,(255,255,255),1 ,2)
cv.imshow("OUT",img2)
```

Results:







```
Enter Zoom Value from the map: 20
H= 1080 W= 1920
750 358
581 508
700 642
866 493
226
179
223
178
[[750, 358], [581, 508], [700, 642], [866, 493]]
[750, 581, 700, 866]
[358, 508, 642, 493]
absoulte area is 1670.625 m^2
Using average area technique:
1690.8860759493673
750 357
822 140
229
229
height is 84.75 m
volume is 141585 m^3
mass of structure is 339805125 kg
safe area of building is 22553.24625 m^2
>>>
```

Conclusion and Future Scope:

Through this unparalleled model, I was able to identify the areas with high risk in my city and this can be implemented to places across the world.The user has to save a Google Maps Image to their device, following which my software will crop and allow the user to interact with it to specify the vertices and shadow length of the structure. Meanwhile, the software will calculate the structure's height, area, and volume using the various functions I've defined in it. The software is very user friendly and acts as a low cost and accessible solution with high levels of accuracy. Our algorithms are the core of the project that enable smart governance at city and suburb level to gauge the impact. After teaching our software through constant data feeding, we will soon be able to map clusters of spaces in various cities as gradients and find areas with the most risk. This will help curve economic costs as well as prevent life loss.

This software and algorithm could, in the future, also be implemented to other structures with various shapes, like bridges and stadiums, which will essentially help us collect data from all around the world and help with infrastructure development. As I continue to strive to make my software more efficient, I am simultaneously studying the volume of the building and writing algorithms that can correlate it with the mass and centre of gravity all the while predicting the angle and the direction of the tilt.

References

1. Earthquakes - British Geological Survey, https://www.bgs.ac.uk/discovering-geology/earth-hazards/earthquakes/
2. What Is an Earthquake? | NASA Space Place – NASA Science for Kids, https://spaceplace.nasa.gov/earthquakes/en/
3. seismograph | Definition & Facts | Britannica, https://www.britannica.com/science/seismograph
4. What is the Cost of Disaster? — Optimum Seismic, https://www.optimumseismic.com/earthquake-preparedness/what-is-the-cost-of-disaster/
5. Earthquakes, https://www.who.int/health-topics/earthquakes#tab=tab_1
6. How Do We Measure Earthquake Magnitude? | UPSeis | Michigan Technological University, https://www.mtu.edu/geo/community/seismology/learn/earthquake-measure/
7. What is an earthquake and what causes them to happen? | US Geological Survey, https://www.usgs.gov/faqs/what-earthquake-and-what-causes-them-happen#:~:text=An%20earthquake%20is%20caused%20by%20a%20sudden%20slip%20on%20a%20fault.&text=When%20the%20stress%20on%20the,and%20the%20North%20American%20Plate
8. How Much Economic Damage Do Large Earthquakes Cause? - Federal Reserve Bank of -Kansas City, https://www.kansascityfed.org/oklahomacity/oklahoma-economist/2016q1-economic-damage-large-earthquakes/
9. Mustafa Erdik,"Urban Earthquake Risk", Engineering Conferences International, http://dc.engconfintl.org/geohazards/17

- What are the Effects of Earthquake on Structures? - The Constructor
- Indian Standards For Earthquakes
- Earthquake Risk Reduction in Buildings and Infrastructure Program | NIST
- How Earthquake-Proof Buildings Are Designed | BigRentz