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A CRITICAL REVIEW ON BASE ISOLATION TECHNIQUES FOR ITS APPLICATION AS EARTH QUAKE RESISTANT BUILDINGS WITH PARTICULAR NEED/ADHERENCE IN EASTERN UTTAR PRADESH

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ABSTRACT

An Earthquake is a natural phenomenon which produces surface waves ultimately causing the vibration of the ground and structures standing on it. Depending on the characteristics of these vibrations the ground may develop cracks, fissures and settlements ultimately resulting ground movement and sometimes proves violent and damages of structures at a very large scale, though earthquake itself is not a disaster. Complete protection of a building due to generation of earthquake waves poses unique challenges in the form of protection of more vertical sensitive non-structural components ,mitigation of total uplift tension demand generated by overturning forces in slender members and shifting or sliding of the superstructure .For the prevention of buildings and other civil engineering structures from the damaging effect of earthquake ground shaking ,base isolation is a widely adopted techniques all over the world. This technique consists of shifting the natural period of the structure to the long period range by placing horizontally flexible isolation devices at the base of the structure to physically decouple it from the ground. This allows the superstructure to remain elastic or nearly elastic following a design level event and minimize the likelihood damage to the civil engineering structures. The decrease of acceleration and drift in structures through base isolation devices makes it one of the most effective strategies operational performances following a large and infrequent earthquake. There are three major types commonly used bearings as isolated devices namely elastomeric bearings (rubber), rollers and ball bearings, slider bearing (curved, pendulum & flat) and also four types of dampers, i.e. steel, oil ,lead and friction dampers with disc springs are the essential component of a base isolation system. This paper not only summarizes the base isolation techniques, reviews of the current practices and past researches but also need/adherence of these techniques by analyzing the earthquake data of the seven prominent cities/districts of the eastern Uttar Pradesh. This has been achieved by evaluating the each city/district by existing civil engineering structures of cultural / historical / archaeological importance, existing & pace of growth of high rise buildings, depth of alluvial soil over the soil/rock, geological, geographical and topographical features and earthquake magnitude.

KEYWORDS: Base isolation techniques, roller and ball bearings, slider bearings, alluvial soil cover, earthquake waves ,eastern Uttar Pradesh.

INTRODUCTION

Application of base isolation techniques goes back to hundreds of years ago and even to ancient times. Installing pieces of wood between the foundation and the walls of buildings is among the earthquake resistant construction techniques that have been applied in some areas in the past. Eastern Uttar Pradesh is located in an active seismic area having common boundary with Nepal and is affected by the frequently observed heavy casualties and damages due to destructive earthquakes and its aftershocks in Nepal. Therefore, in the past different techniques such as filling the stone ballast of different sizes in layers having large size stone layer below the small sizes layers in thickness varying from 15cm-30cm, Sand filling in foundation and sides of the walls, and using pieces of woods (timbers) underneath the load bearing walls were applied in earthquake resistant construction. Sand filling below the foundation and sides of walls recovers the cracks developed in the ground during earthquakes.

Two main concepts of earthquake resistance have been applied in construction of buildings in past. First type is based on making the civil engineering structure flexible by providing base isolation devices thus decoupling the ground motion with the vibration of the structure and the other considered the whole building as a single unit i.e. rigid/balanced structure. Many traditional buildings are constructed allowing the rolling movement thus making the building structure flexible on the base isolated foundations. The rolling of the buildings is achieved by providing foundations of the buildings in the form of timber layers. Each layer of the timber is capable of rolling to each other and dissipating the excess energy induced by the earthquake. In the second techniques buildings are constructed assuming the foundation and civil engineering structures as a single unit or rigid and structures are braced at the corners with both horizontal and vertical wooden members and wooden columns provided are anchored at the roof and at the foundation. Timber tie beams, columns and bracings act as monolithic structure and the whole structure behaves in an integrated manner during earthquake. A seismic vibration reduction system with two Teflon plates with rubber in between installed between the basement ceiling and the ground floor columns of the building has been found satisfactory to prevent the damages.

BASE ISOLATION TECHNIQUES

The traditional design practices of increasing the resistance is now becoming old day practice and base isolation techniques are gaining much importance specially for the preservation of museums, data storage, irreplaceable and valuable buildings and hospitals due to development of large plastic deformation in structural element that are irreparable and cannot be restored even after the earthquake in former case. Traditional structure without isolation suffers important floor offsets during earthquakes, which could lead to the structure collapse. While maximum deformation at the base is produced by isolated structures similar to vibrating solid body. A comparison between the behavior of the isolated structure and fixed base structure under the effect of an earthquake is shown in fig1. In case of the isolated structure the applied side force is reduced and redistributed over the entire height of the structure

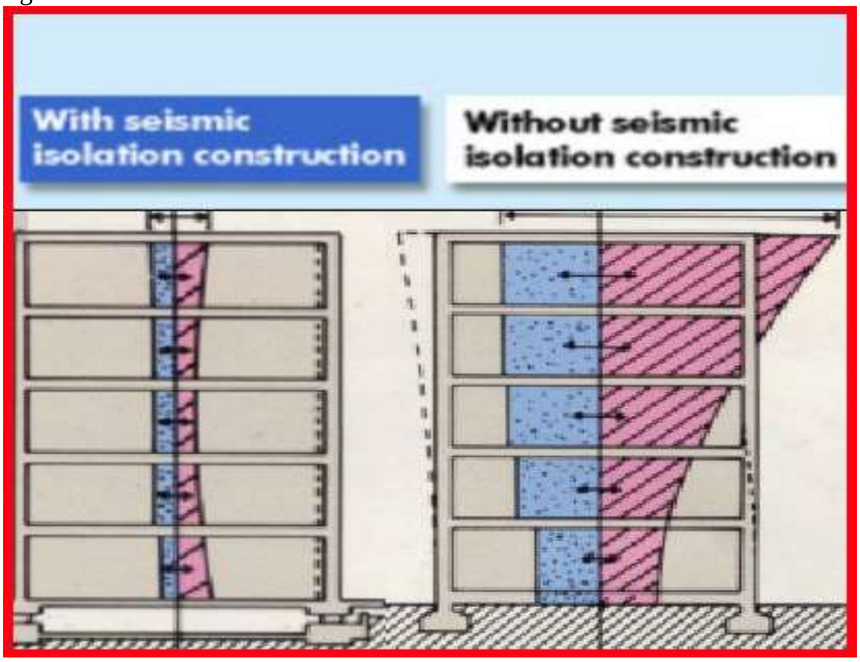

Fig 1: Response of Base Isolated Structure

Base isolation is one of the most widely implemented and accepted seismic protection system in earthquake prone areas recently developed either to reduce the earthquake forces acting on the structures or absorb a part of the seismic energy. It is a design methodology which essentially isolate the structure from potentially dangerous ground motions thus unoccupy the structure for the damaging effects of the ground motion. Base isolation is the seismic isolation system located under the structure for the purpose of decoupling the foundation from superstructure for allowing the building to behave more flexibly .This improves its response to an earthquake due to additional means of energy dissipation by reducing the transmitting vibrations into the superstructure.

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Fig2: Principle of Base Isolation System

Base isolation not only reduces the seismic demand of structure, cost of structure, damages caused during the earthquake but also it enhances the performance of structure under seismic load and after the earthquake , safety of the structure and preservation of property system. The characteristics of proper designed seismic isolation systems should be its flexibility to increase period of vibration and thus reduce force response and energy dissipation to control the isolation system displacement through rigidity under low load levels such as wind and minor earthquakes. Basic requirement of an isolated system are flexibility, damping and resistance to vertical or other service loads.. Flexibility plays very important role in context to response modification. . Rotation friction dampers is designed to dissipate seismic energy and protect buildings from structural and structural damage during earthquakes moderate and severe The overall response is mainly affected by damper properties as geometry, frictional sliding moment and viscoelastic properties combined with the structural natural frequencies. This economic device is easy to manufacture and implement in structures due to material availability. It can easily be replaced /readjusted if damage occur or any dislocation occurs., Damper Friction is Used to solve the problem of the nearby distance between buildings . Response reduction using dampers is independent of the structure stiffness. Soft-story and Sleeved Piles and Rocking Isolation systems are other major systems. Base isolation and seismic dampers can be employed to minimize inter-story drifts and floor accelerations via specially designed isolation and dampers system at the structural base, or at higher levels of the superstructure.

Elastomeric Rubber Bearing

The most important rubber bearings used in isolation structures formed of horizontal layers of low damping synthetic or natural rubber with lead core known as lead rubber bearing in thin layers bound between steel plates. These bearings are flexible under lateral loads and supports high vertical loads with very small deformations. Bulging of rubber layers in bearings is checked by steel plates. Lead cores are provided to increase damping capacity by generating hysterical damping as plain elastomeric bearings does not provide significant damping. They are usually soft in horizontal direction and hard in vertical direction. Elastomeric Bearing Pads provide a connection to control the interactions of loading and movements between parts of a structure, usually between superstructure and substructure. Since rubber is a viscoelastic material and its deformation under compressive load depends upon the shape of structure ,design of rubber bearing pads reinforced with plates, which are chemically bonded to the elastomer provide stable size for specified loads and motions of a axis.

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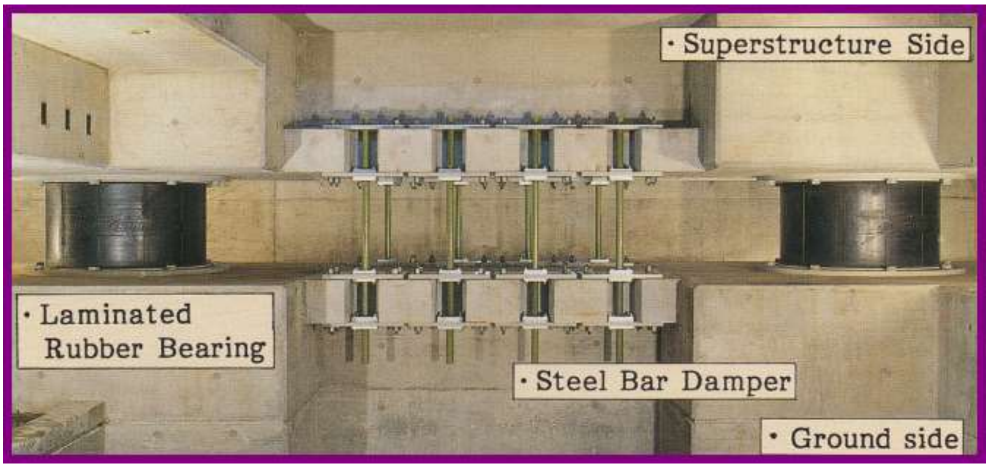

Fig 3: Elastomeric Rubber Bearing

Roller &Ball Bearing

Roller and ball bearings are used in bridges and in machinery isolation to a large scale bearing . It consists of cylindrical rollers and balls and is sufficient to resist horizontal movements and damping depending on the material used. This can be easily applied in base isolation without any changes in design ,shape or technology.

Fig 4: Roller & Ball Bearing Based Isolated Structure

Slider Isolation Systems

Slider isolation systems, which rely horizontal sliding surfaces cause large residual transitions in the structure because of the absence of mechanical forces return, so the need for additional devices to ensure returns forces . The insulation system that takes slider sliding surface which form concave and thus secures a waste of energy, mechanical and return to the center after the excitement in the seismic isolation unit .This system limits the transferred acceleration and forces and provides flexibility and force displacement by sliding under varying load.

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Fig5: Sliding Bearing Based Isolated Structure

Steel Springs

Steel springs are heavy-duty isolators used for building systems and industry. Additional isolation is achieved by steel spring mounting on a concrete block. Both horizontal and vertical vibrations are controlled since these are flexible in both directions.

Fig6: Steel Spring Based Isolated Structure

Recent Innovative Base Isolation Techniques

Seismic retrofitting of existing buildings of historical and cultural importance poses challenge for both designer and construction engineers on the ground of historical ,economic aspects and more due to lack of technical informations at the time of the construction of the buildings/structures. While proposing a seismic-retrofit scheme for a historical building, one should keep in mind that it should be compatible with existing materials, be least intrusive, monitor able and removable.

A novel base-isolation technique for the up-gradation of existing buildings against seismic actions which does not involve any alteration in existing buildings, and it is monitor able and removable may be carried out by uncoupling of soil under, and around the building, with the help of closely spaced micro tunnels, trenches and retaining walls. Closely spaced micro tunnels will lay under the foundation of building, running parallel to one

of the dimension of the building, and base-isolation devices will be fitted in lining of these micro tunnels. These closely spaced micro-tunnels, along with the trenches and retaining walls around the building, will isolate the structure from seismic actions. This assembly of micro tunnels, fitted with isolation devices, and trenches, around the building, will be able to filter seismic forces in both directions of building. The construction of these micro-tunnels, for realization of innovative base-isolation technique, is the most critical phase, because it can have a detrimental effect on building.
The recent technique used in japan consisting of seismic isolation construction with the use of two types of massive bearings that support the entire building i.e. laminated rubber bearing consisting of alternate layers of rubber and steel plate swaying left and right to isolate the building from the ground tremors and the sliding seismic isolator combining laminated rubber bearing with resins acting as a sliding mechanism is capable to to absorb strong tremors. These seismic isolation techniques prevent the damage to the buildings specially keeps the furniture inside from toppling by reducing seismic intensity of the top floor up to a level of about thirty percent with respect to the ground.

RESEARCH METHODOLOGY

After identification of problem and setting the objectives, the methodology has been carefully designed to achieve these objectives. This paper is basically a theoretical research based on the previous researches in the field of base isolation techniques. Various literatures are reviewed and analyzed in an integrated manner. All the data used in this paper is secondary data from literature surveys and various researches concentrated on earthquake, seismic isolation, eastern U.P and Nepal. These data have been collected, analyzed, rearranged and compared for the achievement of the objective.

Area Under study

The Eastern Uttar Pradesh falls in a region of moderate to high seismic hazard. Historically, parts of this region have experienced seismic activity in the magnitude range 5.5-8.0. Approximate locations of selected cities/districts and basic political state boundaries along with Nepal, which is the major source of earthquake in this region are displayed in figure 7.

Fig 7: Map of Eastern Uttar Pradesh Showing Selected Locations

Seven representative cities/districts were selected covering the circumference of the eastern Uttar Pradesh and most populous locations where possible damage due to the earthquake is inevitable. The common characteristics of all the locations are that these are situated on the bank of a river and the origin of the earthquake in this region are Nepal earthquakes. The Eastern U.P. has a very damp and usually very hot climate with cool, dry winters from mid-October to mid-February and dry, hot summers from April to Mid-June. The rainy season is from July to September, when this area gets an average rainfall of 90cm from the south-west monsoon winds, and occasionally frontal rainfall will occur in January. Summer temperatures can range from 32 to 47 degrees Celsius. In winter the maximum temperature is around 25 °C and the minimum is in the 3°C- 6 °C range. Fog bound is quite normally seen in these areas almost every year from late-December to mid January. Occasionally, it experiences colder winter spells than places like Shimla and Mussoorie which are situated way high up in the Himalayas. The study areas ranging its distance ranging 355km-627km from Nepal capital Kathmandu and population ranging from 16.20lakhs-59.60lakhs that represent the characteristic features of eastern UP are no more exceptions as shown in Table1.

Table1. Selected Cities In Eastern Uttar Pradesh

Selected City/District	**Description**	**Area**	**Population**	**Growth Rate**	**Distance From Kathmandu**
Lucknow	Situated on both the bank of Gomti River	2528	45.90	26.00%	616
Faizabad	Situated on the bank of River Ghaghra (locally known as Saryu)	2765	24.75	18.50%	459
Gorakhpur	Situated on both the bank of Rapti River	3325	44.50	18.00%	355
Varanasi	Situated on both the bank of Ganga River	1578	36.75	17.00%	496
Allahabad	Situated on both the bank of Ganga River	5482	59.60	20.75%	627
Sonebhadra	Situated on both the bank of Sone River	6788	18.65	27.00%	603
Azamgarh	Situated on both the bank of Tamasa (tauns) River	4,234	16.20	17.00%	413

The city wise characteristic features of existing civil engineering structures of cultural/historical/archaeological importance, existing& pace of growth of high rise buildings and geological/geographical characteristics are as follows:

Lucknow

Lucknow , the capital of the state of Uttar Pradesh is bounded on the east by Barabanki, on the west by Unnao, on the south by Raebareli and in the north by Sitapur and Hardoi. Many Mughal and British era buildings lying in the old part of the city reflect the unique style and architecture and still these buildings such as Imambaras, mosques, Islamic shrines / secular structures such as enclosed gardens, baradaries, and palace complexes are the places of interests for engineers . Bara Imambara in Hussainabad is the largest hall in Asia without any external support from wood, iron or stone beams. The 60 feet (18 m) tall Rumi Darwaja_, built by Nawab Asaf-ud-daula in 1784, served as the entrance to the city of Lucknow. The highest clock tower in India exists in Lucknow in the form of Ghanta ghar. Lucknow has many high rise buildings ranging from 50m-95m and no of floors ranging from13-25.In addition many high rise structures in golf city of height 125-130 m are under construction shown in Table 2:

Table 2. List of Tall Buildings in Lucknow

Sr	**Name**	**Area**	**Height**	**Floors**	**Year**
1	JP Convention Center	Gomti Nagar	95 metres	19	2016
2	Sahara Hospital	Gomti Nagar	85 metres	25	2010
3	Shakti Bhawan	Ashok Marg	80 metres	15	1973
4	Renaissance Hotel	Gomti Nagar	80 metres	16	2015
5	Metro City	Nishatganj	78 metres	16	2009
6	Parshvanath Planet	Gomti Nagar	70 metres	18	2011
7	Omaxe Heights	Shaheed Path	63 metres	14	2010
8	OCR Building	Burlington	54 metres	14	1981
9	La Place Colony	Hazrat Ganj	50 metres	13	1982
Tallest Building Under Construction					
Sr	**Name**	**Area**	**Height**	**Floors**	**Expected year of completion**

Sr	Name	Area	Height	Floors	Year
1	JP Convention Center	Gomti Nagar	95 metres	19	2016
1	Golf gateway tower	Golf city	110 metres	32	2019
2	Parath aryavrat	Golf city	108 metres	31	2018
3	Crest golf ridge tower	Golf city	105 metres	30	2017
4	F Crown	Golf city	105 metres	29	2019

Faizabad-Ayodhya

The Faizabad , the old capital of awadh, is the district headquarter and is a municipal corporation with Ayodhya in the state of U.P., India. Nawabs graced Faziabad with many historical and beautiful buildings, e.g. Gulab Bari, Moti Mahal and the tomb of Bahu Begum. Gulab Bari is a striking building of fine properties, standing in a garden surrounded by a wall, approachable through two large gateways. Rising up to 42 meters the tomb of Bahu Begam also affords a magnificent view of the Faizabad town and its beautiful surroundings These buildings are particularly interesting for their assimilative architectural styles. Ayodhya as one of the seven most sacred cities of India is predominantly a religious destination with its historical significance and sacred temples. The Atharvaveda described Ayodhya as "a city built by God and being prosperous as paradise itself. The places of interest in this city are Hanuman Garhi, Ramkot, Nageshwar nath temple and Chakravarti Maharaj Dasharath Mahal. Hanuman Garhi,situated in the center of town approachable by a flight of 76 steps and the massive four-sided fort with circular bastions at each corner having a temple of Hanuman inside and Ramkot standing on elevated ground in the western city are the main places of worship in Ayodhya, . The city is bounded on the east by Basti, on the west by Brabanki, on the north by Gonda and in the south by Ambedkarnagar and Sultanpur.

Gorakhpur

Gorakhpur is a city located near the Nepal border, 280 kilometres east of the state capital Lucknow having the Gorkshanath Temple (Gorakhnath Math).Gorakhpur is one of the most flood-prone districts in Eastern Uttar Pradesh. One fifth of the population is affected by floods in every three or four year consecutive intervals and cause huge loss of life, health and livelihoods for the poor inhabitants, damage to public and private property. Ramgarh Tal is a lake located near Gorakhpur. It covers an area of 723 hectares (1,790 acres) with a circumference of 18 kilometres .Gorakhpur has its own cultural and historical importance. It belongs to the Great Lord Buddha, founderof Buddhism and Lord Mahavir, 24th tirthankar, founder of Jainism. Gorakhpur is situated at the confluence of the rivers Rapti and Rohin , is one of the fastest growing in India’s mid-Gangetic plains. Today westernized shopping malls, reputed educational institutes, health care facilities, commercial centers, recreation sites, administrative buildings and multi storied houses co-exist with decrepit slums. Haphazard development processes have created many problems. Increasing population pressure has severely stressed the capacities of the city’s natural, social, institutional and infrastructure systems.

Varanasi

Varanasi or Banaras or Kashi is a city in the U.P.state of North India, 320 kilometres south-east of the state capital, Lucknow, and 121 kilometres east of Allahabad.and 63 kilometres south of Jaunpur The spiritual capital of India, it is the holiest of the seven sacred cities (Sapt Puri) i.e.Ayodhya, Mathura, Gaya, Kasi, Kanchi, Avantika, and Dvaravati known as the givers of liberation in Hinduism and Jainism, and played an important role in the development of Buddhism. Varanasi has been a cultural centre due to Hindu’s belief that death in the city will bring salvation, making it a major centre for pilgrimage. The city is famous for ghats such as Dashashwamedh Ghat, the Panchganga Ghat, the Manikarnika Ghat and the Harishchandra Ghat in the form of steps of stone slabs.Former two ghats are used for performing ritual ablutions by pilgrims whereas the last two being where Hindus cremate their dead. The Ramnagar Fort, near the eastern bank of the Ganges, was built in the 18th century in the Mughal style of arcitecture with carved balconies, open courtyards, and scenic pavilions. Among the estimated 23,000 temples in Varanasi are Kashi Vishawanath Temple of Shiva, the Sankat Mochan Hanuman Temple, and the Durga Temple. . One of Asia's largest residential universities is Banaras Hindu University (BHU). Varanasi is located at an elevation of 80.71 metres in the centre of the Ganges valley of North India, in the Eastern part of the state of Uttar Pradesh, along the left crescent-shaped bank of the Ganges, averaging between 15 metres and 21 metres above the river. Varanasi is situated between the Ganges confluences with the Varuna and the Assi stream seperated around 4 km serves as a sacred journeying route for a visit to a Sakshi Vinayak Temple.

Allahabad

Allahabad also known as Prayag is a city in the Indian state of Uttar Pradesh and the administrative headquarters of Allahabad District, the most populous district in the state. As of 2011, It is the seventh most populous city in the state, twelfth in the Northern India and thirty-sixth in India. Allahabad has many buildings featuring Indo-Islamic and Ind-Saracenic architecture. This city played an important role in the development of high rise buildings /structures in context to the formation of modern India and is one of the fastest growing city,which has been the center of attraction of builders/real estate developers. The prominent builders in the city are Omaxe, Rudra Real Estate, Sangam Real Estate and Construction,3G Crimson,Citizen Housing and New modern Build well.

Sonbhadra

Sonbhadra with its headquarter at Robertsganj, 2nd largest district of Uttar Pradesh, is the only district in India which borders four states namely Bihar, Chhattishgarh, Jharkhand and Madhya Pradesh and eight districts namely Chandauli, Garhwa, Kaimur, Koriya, Mirzapur, Rohtas, Sarguja and Singrauli. Sonbhadra district is an industrial zone and it has lots of minerals like bauxite, limestone, coal,gold etc. Sonbhadra lies between vindhya and Kaimur hills is hilly region with natural beauty. The forts Located in the district are Agori Fort - ruled by Madan Shah ,Vijaygarh Fort - ruled by Kashi Naresh Chet Singh and Sodhrigarh Durg- ruled by Garhwal kings. The Sone River flows through the in the centre of the district from west to east and its tributary the Rihand River connects the south in the highlands of Surguja district of Chhattisgarh. Sonbhadra is located in the second hill ranges of the UP/MP i.e. Vindhyachal mountain and the Govind Ballabh Pant Sagar, a natural reservoir on the Rihand , Obra and Renukoot , the bigger and developed cities enable the southern region of Sonebhadra as the " Energy Capital of India ". It has three coal-based thermal power plants at Shaktinagar (2000 MW),Vindhyanagar (4760 MW) and Bijpur (3000 MW]and power stations are at Anpara , Obra , Renusagar (Hindalco) and Pipri-Hydro (UPRVUNL).Due to rich in lime stone and coal mines this region emerged as industrial heaven in the form of head quarters of NCL ,Hindalco at Renikut, Cement facctories at Dala, Chunar and Churk, Electricity generation plant at Obra and Anapara, Hitech carbon company and Kanoria chemicals.

Azamgarh

Azamgarh is believed to be holy land for saints and lies between the Ganges and the Ghaghara consisting of parallel ridges having in between low lying rice lands. Azamgarh district is surrounded by the districts of Mau in the east, Gorakhpur and Ambedkarnagar in north, Sultanpur in west ,Ghazipur and Jaunpur in the south- The summits of the ridges are depressed into beds or hollows along the direction of the rivers flow. Azamgarh soil is quite suitable for agricultural purposes and plays a major part in agricultural production of all types of crops i.e. kharif, rabi and Jayad

Statistical Analysis

The factors affecting the destructiveness of an earthquake depends upon the various factors such as location, magnitude, depth of earthquake, distance from the epicenter ,local geological conditions and architecture. It is a well known fact that an earthquake hitting the populated area is more destructive than an earthquake hitting the unpopulated or middle of the water body and more energy in an earthquake, the more destructive an earthquake. The depth of the earthquake may be at anywhere form the surface of the rock/soil to the 1000km below the surface. Deeper earthquakes are less destructive because their energy dissipates before it reaches the surface. The building shape should be regular and balanced as irregular shape/unbalanced buildings in terms of plan or elevation are prone to suffer earthquake damages. The difference between the center of gravity and the center of its earth quake resisting elements beams, shear walls, columns and braces a torsional deformation around the center of the earthquake resisting elements caused by earthquake. If the building heights of two parts are different they quake independently at the time of an earthquake and may deform in reverse directions. The buildings up to 25m height show the higher damage if the thickness of the soil cover is less .This happens because of the soil cover which acts as a filter and allow some ground wave to pass through it. The earthquakes in Nepal is the origin of all earthquakes of maximum magnitude in eastern U.P. and this region felt bouts of aftershocks .The details of the earthquake in Nepal and selected cities of maximum and minimum magnitude are shown in table3 respectively. However the minimum earthquake is contributed by the Nepal, Madhya Pradesh and Bihar.

Table 3. Earthquake of Maximum & Minimum Magnitude

City		Year	Magnitude	Depth	Epicenter
Nepal	Maximum	15Jan,1934	8.4	15km	Lahan Eastern Region Nepal
	Minimum	1966	6.3	37Km	Nepal-India Border

Lucknow Maximum	2015	7.8	8Km	Bharatpur Central Region, Nepal
Minimum	1999	4.3	33Km	Tikapur,Far Western,Nepal
Faizabad Maximum	2015	7.8	8Km	Bharatpur Central Region, Nepal
Minimum	1996, 2011 & 2013	4.0	10Km 35Km 80Km	Besisahar,Nepal
Gorakhpur Maximum	2015	5.5	8km	Kothari, Nepal
Minimum	2015	3.7	10Km	Hatauda Central Region, Nepal
Varanasi Maximum	1934	8.0	15km	Lahan Eastern Region Nepal
Minimum	1996	3.8	33Km	Singrauli, Madhya Pradesh
Allahabad Maximum	1934	8.0	15km	Lahan Eastern Region Nepal
Minimum	1996	3.8	33Km	Singrauli, Madhya Pradesh
Sonbhadra Maximum	1934	8.0	15Km	Lahan Eastern Region Nepal
Minimum	1996	3.9	33km	Singrauli, Madhya Pradesh
Azamgarh Maximum	2015	7.8	8Km	Bharatpur Central Region, Nepal
Minimum	1988	3.8	94Km	Ramnagar, Bihar, India

It is observed that maximum magnitude of the earthquake was 8.0 in Varanasi ,Allahabad and Sonbhadra in 1934 against the originating earthquake of the magnitude 8.4 from the Lehan Eastern region, Nepal :maximum magnitude of the earthquake was 7.8 in Lucknow ,Faizabad and Azamgarh in 2015 against the originating earthquake of the magnitude from the Bharatpur Central Region Nepal. Gorakhpur has experienced earthquakes of lowest magnitude range3.7-5.5from the earthquakes originating from Nepal in 2015.The earthquakes maximum ,minimum, average magnitudes and frequency of earthquake for different selected cities/districts along with Nepal are presented in table 4:

Table 4. Earthquake Details of Study Area In Terms of Magnitude & Frequency

City/District	Maximum	Minimum	Average	No of earth quakes in 100 years
Nepal	8.4	6.3	7.18	8
Lucknow	7.8	4.3	5.10	20
Faizabad	7.8	4.0	5.14	20
Gorakhpur	5.5	3.7	4.44	20
Varanasi	8.0	3.8	6.02	14
Allahabad	8.0	3.8	5.70	15
Sonbhadra	8.0	3.9	5.90	15
Azamgarh	7.8	3.8	5.15	20

The parameters selected for the statistical analysis were density of population, earthquake maximum, minimum and average magnitude, earthquake frequency, depth of soil cover and rocky surface thickness below the soil cover from various surveys were collected and are shown in table5.

Table 5. Selected Parameter (Datas) of different Cities/Districts in Eastern U.P.

Parameter/City	Density of population	Earthquake Magnitude Maximum Minimum	Frequency of	Depth of soil cover	Rocky Surface Thickness(km)

	(persons/km ^{2})	Average			Earthquake	(m)	
Lucknow	1815	7.8	4.3	5.10	20	1000-1500	2.5
Faizabad	895	7.8	4.0	5.14	20	1500-2500	4.5
Gorakhpur	1338	5.5	3.7	4.44	20	3000-6000	6.0
Varanasi	2329	8.0	3.8	6.02	14	1000-2000	14.0
Allahabad	1087	8.0	3.8	5.70	15	500-800	8.0
Sonbhadra	277	8.0	3.9	5.90	15	300-400	6.5
Azamgarh	383	7.8	3.8	5.15	20	1800-3000	4.0

As the data of population density, rocky surface thickness , depth of soil cover of Sonbhadra and Nepal shows similar trend ,very high/low and belongs to the top two existing mountain ranges of UP/MP ,hence the control parameter for the statistical analysis of these parameters is assumed as average of the parameters all other locations for statistical analysis. The percentage variation of the parameters of individual city/district has been compared with assumed average control parameter and Nepal earthquake data and are shown in table 6:

Table 6. Variation of Parameters With Respect to Control Para meter

Parameter/City	Density of population (persons/km ^{2})	Earthquake Magnitude Maximum Minimum Average			Frequency of Earthquake	Depth of soil cover (m)	Rocky Surface Thickness(km)
Control P	1161	8.4	6.3	7.18	8	1300-2314	6.5
Lucknow	56.33	7.14	31.75	28.97	150	30.83	61.53
Faizabad	22.91	7.14	36.50	28.41	150	10.67	30.77
Gorakhpur	15.25	34.52	41.27	38.16	150	149.03	07.69
Varanasi	100.60	4.76	40.53	16.16	75	16.99	115.39
Allahabad	63.74	4.76	40.53	20.61	87.5	64.03	23.07
Sonbhadra	76.14	4.76	38.09	17.82	87.5	80.63	00.00
Azamgarh	67.01	7.14	40.53	28.27	150	32.81	38.46

The mean value of the parameters representing the earthquake characteristics of the whole eastern Uttar Pradesh has been compared with the Nepal. The standard deviation and difference in parameters(%) are presented in table 7.

Table 7. Comparative Study of Earthquake Parameters With Nepal

Parameter	**Nepal**	**Mean Value**	**Standard Deviation**	**Difference in parameters (%)**
Earthquake Magnitude(Max)	8.4	7.49	0.912	10.83
Earthquake Magnitude(Min.)	6.3	3.9	0.2	38.09
Earthquake Magnitude(Ave)	7.18	5.35	0.55	25.49
Frequencyof earthquake	8	18	2.87	125

CONCLUSION

This paper has attempted to offer not only the review of the recent development in base isolation techniques, which are the necessity of the present for the construction of earthquake resistance buildings but also identification/need of the adoption of these techniques in eastern up has been evaluated. The conclusions are as follows:

(a) Allahabad & Sonbhadra, both having common characteristics having two river basins Ganga-Yamina (Non-existing Saraswati) and Son-Rihand rivers respectively, farthest point from Nepal (source of earthquake of maximum magnitude in these areas) while diversing topographical and geological characteristics, population densities, are the locations where low damage risks due to earthquake exists.

(b) Allahabad located at the foothills of second Vindhyachal hill range of UP/MP after Himalayas mountain range and high alluvium soil cover thickness while Sonbhadra situated on rocky area having cementous property(lime stone) and Son river (a large source of coarse sand) makes both the locations enable of qualitative construction of the buildings/structures on the locality ground. In both cases there is no need of adoption of base isolation techniques and a rigid/balanced structure following earthquake resistance building code should be designed.

(c) The magnitude of earthquake in the Luckow, Faizabad, Azamgarh falls in the moderate damage /risk zone as the alluvium cover acts a "shock absorber" and the rocky surface below the alluvium cover of these has a thickness of about 2.5 km-4.5km for the buildings of height up to 15m.

(d) Due to the rocky surface thickness of about 6Km in the foothills of Himalaya the earth quake effects in Gorakhpur seems to be low as compared to the other districts of Indo gangetic plain. However keeping in view the reverse effect of earthquake vibrations in the high rise buildings due to acting of the soil as filter allowing the earthquake waves to pass through it and growing urbanization in the rapid rate in Lucknow and Gorakhpur, in the buildings more than four or five storey in these areas the base isolation and seismic dampers can be employed to minimize inter-story drifts and floor accelerations via specially designed isolation and dampers system at the structural base, or at higher levels of the superstructure and for providing flexibility to the structures.

(e) Varanasi is the location where existence of buildings /structures fall under the category of high damage risk because of the elevation difference in the different parts of the city, high population density, earthquake magnitude and lower depth of soil cover. The development of high rise buildings within the city area should be avoided. There is much need of the adoption of base isolation techniques .A certificate of earthquake resistance building adopting base isolation techniques and development in the suburban areas must be ensured/permitted.

(f) Survival of so many temples in Varanasi even after the earthquake of such a high intensity is due to the existence of large no. of Ghats in Varanasi which provides a support as shear wall and an open space around the temples//buildings to pass the earthquake waves without damaging effects. Such type of development of Ghats in Faizabad /Ayodhya will enable the city/district buildings and other civil engineering structures to be safe and survive for longer period.

(g) For the protection of existing important buildings of the whole eastern U.P .the recent innovative techniques i.e. combining micro tunneling and seismic isolation techniques should be adopted.

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REFERENCES

[1] Vasu D. Chakravarthy, , BiTouaillon, J. Improvement in Buildings. U.S. Patent 99,973, 15 February 1870.
[2] Constantinou, M.C.; Whittaker, A.S; Kalpakidis, Y.; Fenz, D.M.; Warn, G.P. Performacne of Seismic Isolation Hardware under Service and Seismic Loading; Technical Report MCEER-07-0012;
[3] Fenz, D.; Constantinou, M.C. Behaviour of the double concave Friction Pendulum bearing. Earthq. Eng. Struct. Dyn. 2006, 35, 1403–1424.
[4] Naeim, F.; Kelly, J.M. Design of Seismic Isolated Structures: From Theory to Practice, 1st ed.; John Wiley and Sons: Hoboken, NJ, USA, 1999.
[5] Taylor, A.; Aiken, I. What's Happened to Seismic Isolation of Buildings in the U.S.? Structure 11 March 2011, 10–13; Available online: http://www.structuremag.org/article.aspx?articleID= 1404 (accessed on 30 July 2012).
[6] Clarke, C.S.J.; Buchanan, R.; Efthymiou, M. Structural platform solution for seismic arctic environments-Sakhalin II offshore facilities. In Proceedings of the Offshore Technology Conference, Houston, TX, USA, 2–5 May 2005.
[7] Kelly, J.M. Aseismic base isolation: Review and bibliography. Soil Dyn. Earthq. Eng. 1986, 5, 202–216.
[8] Buckle, I.B; Mayes, R.M. Seismic isolation: History, application, and performance—A world view. Earthq. Spectra 1990, 6, 161–201.
[9] Taylor, A.W.; Lin, A.N.; Martin, J.W. Performance of elastomers in isolation bearings: A literature review. Earthq. Spectra 1992, 8, 279–303.
[10] Kunde, M.C.; Jangid, R.S. Seismic behavior of isolated bridges: A-state-of-the-art review. Electron. J. Struct. Eng. 2003, 3, 140–170.
[11] Symans, M.D.; Cofer, W.F.; Fridley, K.J. Base isolation and supplemental damping systems for seismic protection of wood structures: Literature review. Earthq. Spectra 2003, 18, 549–572.
[12] Taylor, A.W.; Igusa, T. Primer on Seismic Isolation; ASCE and Task Committee on Seismic Isolation: Reston, VA, USA, 2004.
[13] Higashino, M.; Okamoto, S. Response Control and Seismic Isolation of Buildings; SPON Press:London, UK, 2006.
[14] Lake, G.J.; Lindley, P.B. Ozone Attack and Fatigue life of Rubber; Maclaren and Sons LTD: London, UK, 1967; pp. 56–71.n