DOWNLOAD PDF EARTHQUAKE RESISTANT DESIGN AND CONSTRUCTION

Chapter 1 : Can you build an Earthquake proof building

This guide replaces the Home Builder's Guide to Seismic Resistant Construction and all earlier versions of FEMA It presents seismic design and construction guidance for one- and two-family light frame residential structures that can be utilized by homebuilders, homeowners, and other non-engineers, and provides supplemental information to the edition of the International Residential Code.

Seismic loading Seismic loading means application of an earthquake-generated excitation on a structure or geo-structure. It happens at contact surfaces of a structure either with the ground, [4] with adjacent structures, [5] or with gravity waves from tsunami. It is related to the seismic hazard of the location. A structure is normally considered safe if it does not endanger the lives and well-being of those in or around it by partially or completely collapsing. A structure may be considered serviceable if it is able to fulfill its operational functions for which it was designed. Basic concepts of the earthquake engineering, implemented in the major building codes, assume that a building should survive a rare, very severe earthquake by sustaining significant damage but without globally collapsing. Seismic performance assessment[edit] Engineers need to know the quantified level of the actual or anticipated seismic performance associated with the direct damage to an individual building subject to a specified ground shaking. Such an assessment may be performed either experimentally or analytically. Experimental assessment[edit] Experimental evaluations are expensive tests that are typically done by placing a scaled model of the structure on a shake-table that simulates the earth shaking and observing its behavior. Due to the costly nature of such tests, they tend to be used mainly for understanding the seismic behavior of structures, validating models and verifying analysis methods. Thus, once properly validated, computational models and numerical procedures tend to carry the major burden for the seismic performance assessment of structures. Snapshot from shake-table video of a 6-story non-ductile concrete building destructive testing Seismic performance assessment or seismic structural analysis is a powerful tool of earthquake engineering which utilizes detailed modelling of the structure together with methods of structural analysis to gain a better understanding of seismic performance of building and non-building structures. The technique as a formal concept is a relatively recent development. In general, seismic structural analysis is based on the methods of structural dynamics. Numerical step-by-step integration proved to be a more effective method of analysis for multi-degree-of-freedom structural systems with significant non-linearity under a transient process of ground motion excitation. Performance evaluations are generally carried out by using nonlinear static pushover analysis or nonlinear time-history analysis. In such analyses, it is essential to achieve accurate non-linear modeling of structural components such as beams, columns, beam-column joints, shear walls etc. Thus, experimental results play an important role in determining the modeling parameters of individual components, especially those that are subject to significant non-linear deformations. The individual components are then assembled to create a full non-linear model of the structure. Thus created models are analyzed to evaluate the performance of buildings. The capabilities of the structural analysis software are a major consideration in the above process as they restrict the possible component models, the analysis methods available and, most importantly, the numerical robustness. The latter becomes a major consideration for structures that venture into the non-linear range and approach global or local collapse as the numerical solution becomes increasingly unstable and thus difficult to reach. Research for earthquake engineering[edit] Shake-table testing of Friction Pendulum Bearings at EERC Research for earthquake engineering means both field and analytical investigation or experimentation intended for discovery and scientific explanation of earthquake engineering related facts, revision of conventional concepts in the light of new findings, and practical application of the developed theories. The National Science Foundation NSF is the main United States government agency that supports fundamental research and education in all fields of earthquake engineering. In particular, it focuses on experimental, analytical and computational research on design and performance enhancement of structural systems. A definitive list of earthquake engineering research related shaking tables around the world may be found in Experimental Facilities for Earthquake Engineering Simulation Worldwide. Network for Earthquake Engineering Simulation The NSF Hazard Mitigation and Structural Engineering program HMSE supports research on new technologies for improving the behavior and response of structural systems subject to earthquake hazards; fundamental research on safety and reliability of constructed systems; innovative developments in analysis and model based simulation of structural behavior and response including soil-structure interaction; design concepts that improve structure performance and flexibility; and application of new control techniques for structural systems. The cyberinfrastructure, connected via Internet2 , provides interactive simulation tools, a simulation tool development area, a curated central data repository, animated presentations, user support, telepresence, mechanism for uploading and sharing resources, and statistics about users and usage patterns. This cyberinfrastructure allows researchers to: These resources jointly provide the means for collaboration and discovery to improve the seismic design and performance of civil and mechanical infrastructure systems. Earthquake simulation[edit] The very first earthquake simulations were performed by statically applying some horizontal inertia forces based on scaled peak ground accelerations to a mathematical model of a building. Dynamic experiments on building and non-building structures may be physical, like shake-table testing , or virtual ones. Therefore, there is a strong incentive to engage an earthquake simulation which is the seismic input that possesses only essential features of a real event. Sometimes earthquake simulation is understood as a re-creation of local effects of a strong earth shaking. Structure simulation[edit] Concurrent experiments with two building models which are kinematically equivalent to a real prototype. Similarity is some degree of analogy or resemblance between two or more objects. The notion of similarity rests either on exact or approximate repetitions of patterns in the compared items. In general, a building model is said to have similarity with the real object if the two share geometric similarity, kinematic similarity and dynamic similarity. The most vivid and effective type of similarity is the kinematic one. Kinematic similarity exists when the paths and velocities of moving particles of a model and its prototype are similar. The ultimate level of kinematic similarity is kinematic equivalence when, in the case of earthquake engineering, time-histories of each story lateral displacements of the model and its prototype would be the same. Seismic vibration control[edit] Seismic vibration control is a set of technical means aimed to mitigate seismic impacts in building and non-building structures. All seismic vibration control devices may be classified as passive, active or hybrid [20] where: However, the remaining portions of the incident waves during a major earthquake still bear a huge devastating potential. For this, some pads are inserted into or under all major load-carrying elements in the base of the building which should substantially decouple a superstructure from its substructure resting on a shaking ground. The first evidence of earthquake protection by using the principle of base isolation was discovered in Pasargadae , a city in ancient Persia, now Iran, and dates back to the 6th century BCE. Below, there are some samples of seismic vibration control technologies of today. The Incas were among the best stonemasons the world has ever seen [24] and many junctions in their masonry were so perfect that even blades of grass could not fit between the stones. Peru is a highly seismic land and for centuries the mortar-free construction proved to be apparently more earthquake-resistant than using mortar. The stones of the dry-stone walls built by the Incas could move slightly and resettle without the walls collapsing, a passive structural control technique employing both the principle of energy dissipation coulomb damping and that of suppressing resonant amplifications. For this purpose, a steel pendulum weighing metric tonnes that serves as a tuned mass damper was designed and installed atop the structure. Suspended from the 92nd to the 88th floor, the pendulum sways to decrease resonant amplifications of lateral displacements in the building caused by earthquakes and strong gusts. Hysteretic dampers[edit] A hysteretic damper is intended to provide better and more reliable seismic performance than that of a conventional structure by increasing the dissipation of seismic input energy. They have an oval hysteretic loop and the damping is velocity dependent. While some minor maintenance is potentially required, viscous dampers generally do not need to be replaced after an earthquake. While more expensive than other damping technologies they can be used for both seismic and wind loads and are the most commonly used hysteretic damper. Friction dampers FDs Friction dampers tend to be available in two major types, linear and rotational and dissipate energy by heat. The damper operates on the principle of a coulomb damper. Depending on the design, friction dampers can experience stick-slip phenomenon and Cold welding. The main disadvantage being that friction surfaces can wear over time and for this reason they are not recommended for dissipating wind loads. When used in seismic applications wear is not a problem and there is no required maintenance. They have a rectangular hysteretic loop and as long as the building is sufficiently elastic they tend to settle back to their original positions after an earthquake. This type of damper absorbs a large amount of energy however they must be replaced after an earthquake and may prevent the building from settling back to its original position. Viscoelastic dampers VEDs Viscoelastic dampers are useful in that they can be used for both wind and seismic applications, they are usually limited to small displacements. There is some concern as to the reliability of the technology as some brands have been banned from use in buildings in the United States. Straddling pendulum dampers swing Base isolation[edit] Base isolation seeks to prevent the kinetic energy of the earthquake from being transferred into elastic energy in the building. These technologies do so by isolating the structure from the ground, thus enabling them to move somewhat independently. The degree to which the energy is transferred into the structure and how the energy is dissipated will vary depending on the technology used. It was invented by Bill Robinson , a New Zealander. However, for the rather pliant systems such as base isolated structures, with a relatively low bearing stiffness but with a high damping, the so-called "damping force" may turn out the main pushing force at a strong earthquake. The bearing is made of rubber with a lead core. It was a uniaxial test in which the bearing was also under a full structure load. Many buildings and bridges, both in New Zealand and elsewhere, are protected with lead dampers and lead and rubber bearings. Both are in Wellington which sits on an active fault. It is a base isolation device conceptually similar to Lead Rubber Bearing. One of two three-story town-houses like this, which was well instrumented for recording of both vertical and horizontal accelerations on its floors and the ground, has survived a severe shaking during the Northridge earthquake and left valuable recorded information for further study. Simple roller bearing Simple roller bearing is a base isolation device which is intended for protection of various building and non-building structures against potentially damaging lateral impacts of strong earthquakes. This metallic bearing support may be adapted, with certain precautions, as a seismic isolator to skyscrapers and buildings on soft ground. Recently, it has been employed under the name of metallic roller bearing for a housing complex 17 stories in Tokyo, Japan. It is based on three pillars: Snapshot with the link to video clip of a shake-table testing of FPB system supporting a rigid building model is presented at the right. Seismic design[edit] Seismic design is based on authorized engineering procedures, principles and criteria meant to design or retrofit structures subject to earthquake exposure. Nevertheless, seismic design has always been a trial and error process whether it was based on physical laws or on empirical knowledge of the structural performance of different shapes and materials. San Francisco after the earthquake and fire To practice seismic design , seismic analysis or seismic evaluation of new and existing civil engineering projects, an engineer should, normally, pass examination on Seismic Principles [34] which, in the State of California, include: Seismic Data and Seismic Design Criteria Seismic Characteristics of Engineered Systems Seismic Forces Seismic Analysis Procedures Seismic Detailing and Construction Quality Control To build up complex structural systems, [35] seismic design largely uses the same relatively small number of basic structural elements to say nothing of vibration control devices as any non-seismic design project. Normally, according to building codes, structures are designed to "withstand" the largest earthquake of a certain probability that is likely to occur at their location. This means the loss of life should be minimized by preventing collapse of the buildings. Seismic design is carried out by understanding the possible failure modes of a structure and providing the structure with appropriate strength , stiffness , ductility , and configuration [36] to ensure those modes cannot occur. Seismic design requirements[edit] Seismic design requirements depend on the type of the structure, locality of the project and its authorities which stipulate applicable seismic design codes and criteria. The Metsamor Nuclear Power Plant was closed after the Armenian earthquake [38]

The most significant feature in the SDC design philosophy is a shift from a force-based assessment of seismic demand to a displacement-based assessment of demand and capacity. Thus, the newly adopted displacement approach is based on comparing the elastic displacement demand to the inelastic displacement capacity of the primary structural components while ensuring a minimum level of inelastic capacity at all potential plastic hinge locations. In addition to the designed structure itself, seismic design requirements may include a ground stabilization underneath the structure: Therefore, their seismic design is based on criteria far more stringent than those applying to non-nuclear facilities. Doubt has also been expressed over the seismic evaluation and design of certain other plants, including the Fessenheim Nuclear Power Plant in France. Failure modes[edit] Failure mode is the manner by which an earthquake induced failure is observed. It, generally, describes the way the failure occurs. Though costly and time consuming, learning from each real earthquake failure remains a routine recipe for advancement in seismic design methods. Below, some typical modes of earthquake-generated failures are presented. Typical damage to unreinforced masonry buildings at earthquakes The lack of reinforcement coupled with poor mortar and inadequate roof-to-wall ties can result in substantial damage to an unreinforced masonry building.

Chapter 2 : Earthquake-resistant structures - Wikipedia

Earthquake resistant design of buildings depends upon providing the building with strength, stiffness and inelastic deformation capacity which are great enough to withstand a given level of earthquake-generated force. This is generally accomplished through the selection of an appropriate structural.

Objectives of the earthquake engineering The main goals of earthquake engineering are: Understand what happens between buildings and the ground. Understand what strong earthquakes or tsunamis might do to building structures. Design , build and maintain structures to last during an earthquake while following building codes. Tools A properly engineered structure does not necessarily have to be extremely strong or expensive. The most powerful and affordable tools of earthquake engineering are vibration control technologies and, in particular, base isolation. To test seismic performance of a building structure with experiments, it is may be put on a shake-table that behaves like the earth shaking. The earliest shake-table experiments were performed more than a century ago Tsunami preparedness and protection Main page: Those waves can flood coastal areas, destroy houses and even swipe away whole towns. Though tsunami can not be prevented, there are warning systems developed recently which warn the population before the big waves reach the land to let them enough time to rush to safety. Seismic design Seismic design is based on authorized engineering procedures, principles and criteria meant to design or retrofit structures subject to earthquake exposure. Those criteria are only consistent with the contemporary state of the knowledge about earthquake engineering structures. Therefore, a building design which exactly follows seismic code regulations does not guarantee safety against collapse or serious damage. The price of poor seismic design may be enormous. Nevertheless, seismic design has always been a trial and error process whether it was based on physical laws or on empirical knowledge of the structural performance of different shapes and materials. San Francisco City Hall destroyed by earthquake and fire. San Francisco after the earthquake and fire To practice seismic design , seismic analysis or seismic evaluation of new and existing civil engineering projects, an engineer should, normally, pass examination on Seismic Principles which, in the State of California, include: Seismic Data and Seismic Design Criteria Seismic Characteristics of Engineered Systems Seismic Forces Seismic Analysis Procedures Seismic Detailing and Construction Quality Control To build up complex structural systems, seismic design largely uses the same relatively small number of basic structural elements to say nothing of vibration control devices as any non-seismic design project. Normally, according to building codes, structures are designed to "withstand" the largest earthquake of a certain probability that is likely to occur at their location. This means the loss of life should be minimized by preventing collapse of the buildings. 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In addition to the designed structure itself, seismic design requirements may include a ground stabilization underneath the structure: The following topics should be of primary concerns: Nuclear facilities should not jeopardise their safety in case of earthquakes or other hostile external events. Therefore, their seismic design is based on criteria far more stringent than those applying to non-nuclear facilities. Doubt has also been expressed over the seismic evaluation and design of certain other plants, including the Fessenheim Nuclear Power Plant in France. Failure modes Failure mode is the manner by which an earthquake induced failure is observed. It, generally, describes the way the failure occurs. Though costly and time consuming, learning from each real earthquake failure remains a routine recipe for advancement in seismic design methods. Below, some typical modes of earthquake-generated failures are presented. Typical damage to unreinforced masonry buildings at earthquakes The lack of reinforcement coupled with poor mortar and inadequate roof-to-wall ties can result in substantial damage to an unreinforced masonry building. Severely cracked or leaning walls are some of the most common earthquake damage. Also hazardous is the damage that may occur between the walls and roof or floor diaphragms. Separation between the framing and the walls can jeopardize the vertical support of roof and floor systems. Soft story collapse due to inadequate shear strength at ground level, Loma Prieta earthquake Soft story effect. Absence of adequate stiffness on the ground level caused damage to this structure. A close examination of the image reveals that the rough board siding, once covered by a brick veneer, has been completely dismantled from the studwall. Only the rigidity of the floor above combined with the support on the two hidden sides by continuous walls, not penetrated with large doors as on the street sides, is preventing full collapse of the structure. Effects of soil liquefaction during the Niigata earthquake Soil liquefaction. In the cases where the soil consists of loose granular deposited materials with the tendency to develop excessive hydrostatic pore water pressure of sufficient magnitude and compact, liquefaction of those loose saturated deposits may result in non-uniform settlements and tilting of structures. This caused major damage to thousands of buildings in Niigata, Japan during the earthquake. Car smashed by landslide rock, Sichuan earthquake Landslide rock fall. A landslide is a geological phenomenon which includes a wide range of ground movement, including rock falls. Typically, the action of gravity is the primary driving force for a landslide to occur though in this case there was another contributing factor which affected the original slope stability: Effects of pounding against adjacent building, Loma Prieta Pounding against adjacent building. This is a photograph of the collapsed five-story tower, St. During Loma Prieta earthquake, the tower pounded against the independently vibrating adjacent building behind. Effects of completely shattered joints of concrete frame, Northridge At Northridge earthquake, the Kaiser Permanente concrete frame office building had joints completely shattered, revealing inadequate confinement steel, which resulted in the second story collapse. In the transverse direction, composite end shear walls, consisting of two wythes of brick and a layer of shotcrete that carried the lateral load, peeled apart because of inadequate through-ties and failed. Improper construction site on a foothill. Poor detailing of the reinforcement lack of concrete confinement in the columns and at the beam-column joints, inadequate splice length. Seismically weak soft story at the first floor. Long cantilevers with heavy dead load. Earthquake damage in Pichilemu. If a superstructure is not mounted on a base isolation system, its shifting on the basement should be prevented. Insufficient shear reinforcement let main rebars to buckle, Northridge Re inforced concrete column burst at Northridge earthquake due to insufficient shear reinforcement mode which allows main reinforcement to buckle outwards. The deck unseated at the hinge and failed in shear. As a result, the La Cienega-Venice underpass section of the 10 Freeway collapsed. Support-columns and upper deck failure, Loma Prieta earthquake Loma Prieta earthquake: Lateral spreading mode of ground failure, Loma Prieta Ground shaking triggered soil liquefaction in a subsurface layer of sand , producing differential lateral and vertical movement in an overlying carapace of unliquified sand and silt. This mode of ground failure, termed lateral spreading, is a principal cause of liquefaction-related earthquake damage. Beams and pier columns diagonal cracking, Sichuan earthquake Severely damaged building of Agriculture Development Bank of China after Sichuan earthquake: Large diagonal cracks in masonry and veneer are due to in-plane loads while abrupt settlement of the right end of the building should be attributed to a landfill which may be hazardous even without any earthquake. Tsunami strikes Ao Nang, Twofold tsunami impact: Earthquake-resistant construction Earthquake construction means implementation of seismic design to enable building and non-building structures to live through the anticipated earthquake exposure up to the expectations and in compliance with the applicable building codes. Construction of Pearl River Tower X-bracing to resist lateral forces of earthquakes and winds Design and construction are intimately related. To achieve a good workmanship, detailing of the members and their connections should be as simple as possible.

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As any construction in general, earthquake construction is a process that consists of the building, retrofitting or assembling of infrastructure given the construction materials available. The destabilizing action of an earthquake on constructions may be direct seismic motion of the ground or indirect earthquake-induced landslides, soil liquefaction and waves of tsunami. A structure might have all the appearances of stability, yet offer nothing but danger when an earthquake occurs. The crucial fact is that, for safety, earthquake-resistant construction techniques are as important as quality control and using correct materials. To minimize possible losses, construction process should be organized with keeping in mind that earthquake may strike any time prior to the end of construction. Each construction project requires a qualified team of professionals who understand the basic features of seismic performance of different structures as well as construction management. Adobe type of mud bricks is one of the oldest and most widely used building materials. Adobe buildings are considered very vulnerable at strong quakes. However, multiple ways of seismic strengthening of new and existing adobe buildings are available. Key factors for the improved seismic performance of adobe construction are:

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Chapter 3 : Earthquake Proof and Resistant Building Structures | REIDsteel

Construction methods can vary dramatically throughout the world, so one must be aware of local construction methods and resource availability before concluding whether a particular earthquake-resistant design will be practical and realistic for the region.

How can existing buildings be strengthened to resist earthquakes? There are a wide variety of earthquake effects â€" these might include a chasm opening up or a drop of many metres across a fault line. Therefore, it is not possible to design an earthquake proof building which is guaranteed to resist all possible earthquakes. However, it is possible during your design and construction process to build in a number of earthquake resistant features by applying earthquake engineering techniques, which would increase enormously the chances of survival of both buildings and their occupants. What is an earthquake? Both the seabed and the land that we inhabit are formed of a crusty skin of light rocks floating on the soft centre of the earth, which is made of heavier molten rock and molten iron. This crusty skin is not one solid piece but is made up of lumps, separated by faults and trenches, or pressed together into mountains. Some plates are moving apart, particularly in the Mid Ocean Trenches, where molten material pushes up and shoves the plates apart, whilst others are bumping into each other head on, these form mountains like the Himalayas the whole of the Indian Sub Continent is moving northwards and hitting Asia, for example. Some are sliding one over another, like the west coast of the Americas, where the land plates are sliding over the denser ocean bed plates, causing the Andes and the Rockies to be thrust upwards. All of these movements cause earthquakes and usually volcanoes as well. If the movement was steady, about a millimetre or so a year, no one would notice. But the plates tend to jam; the movement carries on, but the material where they touch is stretched, or compressed, or bent sideways. The material deforms like stretching or compressing or twisting a bit of plastic. At some stage it reaches the breaking point along all or part of the joint, then it breaks, and there is a sudden movement. The movement may be tiny or may be several feet; but enormous amounts of energy are released, far more than the biggest Nuclear Bombs. The shock waves from this release of energy shoot out in all directions, like the ripples when you throw a stone in a pond: They can be measured all around the whole world. This is an Earthquake. Prior to the Earthquake there are often little warning shakes, where highly stressed bits break and the plate joints readjust themselves a little, but allow the main join to become more stressed. After the primary Earthquake when the main join has failed and moved, there is another readjustment, and further bits around the fault become overstressed too, and they fail. These aftershocks can themselves be highly energetic Earthquakes. After the Earthquake, the area settles down again. But the movement carries on and the next Earthquake is already building up, remorselessly. People forget and build buildings and structures that are going to kill their children next time when they could ensure that during the design and construction phase some earthquake proof measures have been incorporated. Back to Top What makes a building or structure fail in earthquakes? An Earthquake moves the ground. It can be one sudden movement, but more often it is a series of shock waves at short intervals, like our ripples from the pebble in the pond analogy above. It can move the land up and down, and it can move it from side to side. All buildings can carry their own weight or they would fall down anyway by themselves. They can usually carry a bit of snow and a few other floor loads and suspended loads as well, vertically; so even badly built buildings and structures can resist some up-and-down loads. But buildings and structures are not necessarily resistant to side-to-side loads, unless this has been taken into account during the structural engineering design and construction phase with some earthquake proof measures taken into consideration. This weakness would only be found out when the Earthquake strikes, and this is a bad time to find out. It is this side-to-side load which causes the worst damage, often collapsing poor buildings on the first shake. The side-to-side load can be worse if the shocks come in waves, and some bigger buildings can vibrate like a huge tuning fork, each new sway bigger than the last, until failure. This series of waves is more likely to happen where the building is built on deep soft ground, like Mexico City. A taller or shorter building nearby may not oscillate much at the same frequency. Often more weight has been added to a building or structure at most frequently at greater heights; say another floor and another over that; walls built round open balconies and inside partitions to make more, smaller, rooms; rocks piled on roofs to stop them blowing away; storage inside. This extra weight produces great forces on the structure and helps it collapse. The more weight there is, and the higher this weight is in the building, the stronger the building and its foundations must be to be resistant to side earthquakes; many buildings have not been strengthened when the extra weight was added. Often, any resistance to the sway loading of the building is provided by walls and partitions; but these are sometimes damaged and weakened in the Main Earthquake. The building or structure is then more vulnerable, and even a weak aftershock, perhaps from a slightly different direction, or at a different frequency, can cause collapse. In a lot of multi storey buildings, the floors and roofs are just resting on the walls, held there by their own weight; and if there is any structural framing it is too often inadequate. This can result in a floor or roof falling off its support and crashing down, crushing anything below. Often more weight has been added to building or structure at a higher level, for example another floor, extra walls and partitions, extra storage or even rocks piled on roofs to stop them blowing away. Small cracks appear in the concrete. This was beautifully demonstrated under the Oakland Freeway, where huge round concrete columns crumbled and crumpled. They have now been reinforced with massive belts around them as a result of an earthquake engineering review and to improve structural dynamics. So the ground-to-first floor columns, which carry the biggest loads from the weight and the biggest cumulative sideways loads from the earthquake, are the longest and the least restrained and have the least end fixity. They are often the first to fail. It only takes one to fail for the worst sort of disaster, the pancake collapse so familiar to any one who has seen the results in Armenia, Mexico, Turkey, Iran, Peru, and now Pakistan and Kashmir. Sometimes buildings are built on soft soil; this can turn into quicksand when shaken about, leading to complete slumping of buildings into the soil. Some tall buildings can stay almost intact but fall over in their entirety. The taller the building, the more likely this is to happen, particularly if the building can oscillate at the frequency of the shock waves, and particularly if some liquefaction of soft soil underneath has allowed the building to tilt. Back to Top How can we make buildings resistant to earthquakes with earthquake engineering? To be earthquake proof, buildings, structures and their foundations need to be built to be resistant to sideways loads. The lighter the building is, the less the loads. This is particularly so when the weight is higher up. Where possible the roof should be of light-weight material. If there are floors and walls and partitions, the lighter these are the better, too. If the sideways resistance is to be obtained from walls, these walls must go equally in both directions. They must be strong enough to take the loads. They must be tied in to any framing, and reinforced to take load in their weakest direction. They must not fall apart and must remain in place after the worst shock waves so as to retain strength for the after shocks. If the sideways resistance comes from diagonal bracing then it must also go equally all round in both directions. Where possible, it should be strong enough to accept load in tension as well as compression: And the loads have got to go down to ground in a robust way. If the sideways load is to be resisted with moment resisting framing then great care has to be taken to ensure that the joints are stronger than the beams, and that the beams will fail before the columns, and that the columns cannot fail by spalling if in concrete. Again the rigid framing should go all around, and in both directions. If the building earthquake resistance is to come from moment resisting frames, then special care should be taken with the foundation-to-first floor level. If the requirement is to have a taller clear height, and to have open holes in the walls, then the columns at this level may have to be much stronger than at higher levels; and the beams at the first floor, and the columns from ground to second floor, have to be able to resist the turning loads these columns deliver to the frame. Alternatively, and preferably, the columns can be given continuity at the feet. Such steel grillage can also keep the foundations in place. If the beams in the frame can bend and yield a little at their highest stressed points, without losing resistance, while the joints and the columns remain full strength, then a curious thing happens: If the building was vibrating in time with shock waves, this vibration will tend to be damped out. All floors have to be connected to the framing in a robust and resilient way. They should never be able to shake loose and fall. Again all floors should be as light as possible. They should go all round each column and fix to every supporting beam or wall, in a way that cannot be shaken off. One way of reducing the vulnerability of big buildings is to isolate them from the floor using bearings or dampers, but this is a difficult and expensive process not suitable for low and medium rise buildings and low cost buildings though it may be a good technique for Downtown Tokyo. Generally it is wise to build buildings that are not too high compared to their width in Earthquake areas, unless special precautions are taken. Back to Top When looking at design and construction, how do we earthquake proof buildings? When designing earthquake safe structures the first consideration is to make the highest bit, the roof, as light as possible. This is best done with profiled steel cladding on light gauge steel Zed purlins. This can also have double skin with spacers and insulation. It can have a roof slope between 3 and 15 degrees. Such a slab will be completely bonded to the frame and will not be able to slip off, or collapse. If the building or structure is a normal single storey, then any normal portal frame or other steel framed building, if the design and construction is competently done, will be resistant to Earthquake loads. If it is to have 2 or more stories, more needs to be done to ensure its survival in an earthquake. As with the roof, the floors should be made as light as possible. The first way to do this is to use traditional timber joists and timber or chipboard or plywood flooring. If this is done it is vital that the timber joists are firmly through bolted on the frames to avoid them slipping or being torn off. The frame needs them for stability and the floor must never fall down. A better alternative is to substitute light gauge steel Zeds for the timber joists. These can span further and are easier to bolt firmly to the framework. Then, floor-boards or tongue-and-groove chipboard can easily be screwed to the Zeds. However in Hotels, Apartment buildings, Offices and the like, concrete floors may be needed. In such cases we should reduce the spans to the spanning capacity of composite decking flooring, and pour reinforced concrete slabs onto our decking. The decking is fixed to the joists, the joists into the main beams, the main beams into the columns and the concrete is poured around all the columns. There is simply no way that such floors can fall off the frame.

Chapter 4 : Earthquake-resistant construction | racedaydvl.com

Earthquake Hazards Reduction Program (NEHRP) is to encourage design and building practices that address the earthquake hazard and minimize the resulting risk of damage and injury.

See Article History Earthquake-resistant construction, the fabrication of a building or structure that is able to withstand the sudden ground shaking that is characteristic of earthquakes , thereby minimizing structural damage and human deaths and injuries. Suitable construction methods are required to ensure that proper design objectives for earthquake-resistance are met. Construction methods can vary dramatically throughout the world, so one must be aware of local construction methods and resource availability before concluding whether a particular earthquake-resistant design will be practical and realistic for the region. There is a fundamental distinction between the design of a building and the construction methods used to fabricate that building. Advanced designs intended to withstand earthquakes are effective only if proper construction methods are used in the site selection, foundation, structural members, and connection joints. Earthquake-resistant designs typically incorporate ductility the ability of a building to bend, sway, and deform without collapsing within the structure and its structural members. A ductile building is able to bend and flex when exposed to the horizontal or vertical shear forces of an earthquake. Concrete buildings, which are normally brittle relatively easy to break , can be made ductile by adding steel reinforcement. In buildings constructed with steel-reinforced concrete, both the steel and the concrete must be precisely manufactured to achieve the desired ductile behaviour. Building failures during earthquakes often are due to poor construction methods or inadequate materials. In less-developed countries, concrete often is not properly mixed, consolidated, or cured to achieve its intended compressive strength, so buildings are thus extremely susceptible to failure under seismic loading. This problem is often made worse by a lack of local building codes or an absence of inspection and quality control. Building failures are also frequently attributed to a shortage of suitable and locally available materials. For instance, when a building is designed with steel-reinforced concrete, it is critical that the amount of steel used is not reduced to lower the building cost. However, during an earthquake, lateral and shear loading occurs, which results in tensile and torsional forces on structural elements. Strong construction joints are critical in building a structure that will withstand the shear loading of an earthquake. Since stress is concentrated at the joints between the walls, it is important that all the joints be properly prepared and reinforced. Concrete joints must also be properly compacted and anchored in order to achieve optimum strength. In the case of unreinforced masonry joints mortar joints, such as those found in brick buildings , the anchoring between adjacent walls is especially important. When all the joints are tied together well, the building will act as a single integrated unit, enabling the forces of an earthquake to be transferred from one section to the next without catastrophic failure. Earthquake-resistant construction requires that the building be properly grounded and connected through its foundation to the earth. Building on loose sands or clays is to be avoided, since those surfaces can cause excessive movement and nonuniform stresses to develop during an earthquake. Furthermore, if the foundation is too shallow, it will deteriorate, and the structure will be less able to withstand shaking. The foundation should therefore be constructed on firm soil to maintain a structure that settles uniformly under vertical loading.

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Chapter 5 : Earthquake Resistant Design Techniques - Engineer Feed

This guide provides information on current best practices for earthquake-resistant house design and construction for use by builders, designers, code enforcement personnel, and potential homeowners. It incorporates lessons learned from the Loma Prieta and Northridge earthquakes as well as knowledge gained from the FEMA-funded CUREE.

This energy can be generated by a sudden dislocation of segments of the crust, by a volcanic eruption or even by a manmade explosion. The dislocation of the crust causes most destructive earthquakes. The crust may first bend and then the stresses exceed the strength of rocks, they break. In the process of breaking, vibrations called seismic waves are generated. These waves travel outward from the source of the earthquake along the surface and through the earth at varying speeds depending on the material through which they move. Treatment is required to be given depending on the zone in which the particular site is located. Earthquake occurred in the recent past have raised various issues and have forced us to think about the disaster management. It has become essential to think right from planning stage to completion stage of a structure to avoid failure or to minimize the loss of property. Not only this, once the earthquake has occurred and disaster has taken place; how to use the debris to construct economical houses using this waste material without affecting their structural stability How earthquake resistant construction is Different? Since the magnitude of a future earthquake and shaking intensity expected at a particular site cannot be estimated with a reasonable accuracy, the seismic forces are difficult to quantify for the purposes of design. Further, the actual forces that can be generated in the structure during an earthquake are very large and designing the structure to respond elastically against these forces make it too expensive. Therefore, in the earthquake resistant design post yield inelastic behavior is usually relied upon to dissipate the input seismic energy. Thus the design forces of earthquakes may be only a fraction of maximum probable forces generated if the structure is to remain elastic during the earthquake. For instance, the design seismic for buildings may at times be as low as one tenths of the maximum elastic seismic force. Thus, the earthquake resistant construction and design does not aim to achieve a structure that will not get damaged in a strong earthquake having low probability of occurrence; it aims to have a structure that will perform appropriately and without collapse in the event of such a shaking. Ductility is the capacity of the structure to undergo deformation beyond yield without loosing much of its load carrying capacity. Higher is the ductility of the structure; more is the reduction possible in its design seismic force over what one gets for linear elastic response. Ensuring ductility in a structure is a major concern in a seismic construction. A typical RC building is made of horizontal members beams and slabs and vertical members columns and walls and supported by foundations that rest on the ground. The system consisting of RC columns and connecting beams is called a RC frame. The RC frame participates in resisting earthquake forces. Earthquake shaking generates inertia forces in the building, which are proportional to the building mass. Since most of the building mass is present at the floor levels, earthquake induced inertia forces primarily develop at the floor levels. These forces travel downward through slabs to beams, beams to columns and walls and then to foundations from where they are dispersed to the ground. As the inertia forces accumulate downward from the top of the building as shown in fig3. Roles of floor slabs and masonry walls: Floor slabs are horizontal like elements, which facilitates functional use of buildings. Usually, beams and slabs at one storey level are cast together. In residential multistoried buildings, the thickness of slab is only about mmmm. When beams move in horizontal direction, the slab usually forces the beams to move together with it. In most of the buildings, the geometric distortion of the slab is negligible in the horizontal plane; the behavior is known as rigid diaphragm action. After columns and floors in a RC building are cast and the concrete hardens, vertical spaces between columns and floors are usually filled in with masonry walls to demarcate a floor area into functional spaces. Normally, these masonry walls are called infill walls, are not connected to surrounding RC beams and columns. When the columns receive horizontal forces at floor levels, they try to move in the horizontal direction, but masonry wall tend to resist this movement. Due to their heavy weight and thickness, these walls develop cracks once their ability to carry horizontal load is exceeded. Thus, infill walls act like sacrificial fuses in the buildings, they develop crack under severe ground shaking but help share the load the load of beams and columns until cracking. For a building to remain safe during earthquake shaking columns which receive forces from beams should be stronger than beams and foundations which receive forces from columns should be stronger than columns. Further the connections between beams and columns, columns and foundations should not fail so that beams can safely transfer forces to columns and columns to foundations. When this strategy is adopted in the design, damage is likely to occur first in beams. When beams are detailed properly to have large ductility, the building as a whole can deform by large amounts despite progressive damage caused due to consequent yielding of beams. If columns are made weaker, localized damage can lead to the collapse of building, although columns at storey above remain almost undamaged. Relatively speaking, minor shaking occurs frequently; moderate shaking occasionally and strong shaking rarely. For instance, on average annually about earthquakes of magnitude 5. Or should we design the building to be earthquake proof wherein there is no damage during strong but rare earthquake shaking. Clearly the formal approach can lead to a major disaster and second approach is too expensive. Hence the design philosophy should lie somewhere in between two extremes. The engineers do not attempt to make earthquake proof buildings that will not get damaged even during the rare but strong earthquake; such buildings will be too robust and also too expensive. Instead, engineering intention is to make buildings earthquake resistant, such building resists the effects of ground shaking, although they may get damaged severely but would not collapse during the strong earthquake. Thus, safety of peoples and contents is assured in earthquake resistant buildings and thereby, a disaster is avoided. This is a major objective of seismic design codes through the world. The earthquake design philosophy may be summarized as follows: Thus after minor shaking, the building will be operational within a short time and repair cost will be small and after moderate shaking, the building will be operational once the repair and strengthening of the damaged main members is completed. But, after a strong earthquake, the building may become disfunctional for further use, but will stand so that people can be evacuated and property recovered. The consequences of damage have to be kept in view in the design philosophy. For example, important buildings like hospitals and fire stations play a critical role in post earthquake activities and must remain functional immediately after earthquake. These structures must sustain very little damage and should be designed for a higher level of earthquake protection. Collapse of dams during earthquake can cause flooding in the downstream reaches, which itself can be a secondary disaster. Therefore, dams and nuclear power plants should be designed for still higher level of earthquake motion. Next More Seminar Topics: Are you interested in this topic. Then mail to us immediately to get the full report.

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Chapter 6 : Earthquake Resistant Building Construction | Seminar Report, PPT, PDF for Civil Engineering

Homebuilders' Guide to Earthquake-Resistant Design and Construction presents seismic design and construction guidance for one and two-family light frame residential structures that can be utilized by homebuilders, homeowners, and other non-engineers, and provides supplemental information to the edition of the International Residential Code.

WhatsApp Earthquake resistant design are such designed structures which can withstand earthquake. This earthquake resistant design techniques are helpful in reducing the loss of life and property by preventing the building to collapse during earthquake. However there is no building which will be completely immune during the earthquake. Although earthquake produces more than one type of shocks such as vertical, horizontal and circular. So according to the building codes , such earthquake resistant design on structure are implemented in such a way that the structures should be erect during the seismic activity and should be less liable to the damages. However this also depends on the building materials and building techniques which used in the construction on earthquake vulnerable areas. Such techniques are not used for strengthening the building but it reduces the frequency and pulses of the seismic activity. Earthquake resistance design techniques used in construction: Such technique introduces flexibility to the structure and the structures are supported by the bearing pads. This bearing pads are flexible pads. Different types of base isolator used in the earthquake resistant design are: Also in this earthquake resistant design the building is free to slide both horizontally and vertically. When the seismic waves stops, it back to its original place. Lead rubber bearing employs a high damping. This lead rubber bearing is very much flexible in horizontal direction and very stiff in vertical direction. It was invented by William Robinson. In this method, the dampers absorbs the shock and damp the motion of the building. Building uses to dissipate energy because of its large movement due to shock and due to the increase of internal strain in the building units such as column and beam. This dissipation devices are also called as damping devices So we can decrease the seismic energy by using the energy dissipated devices in the building to absorb the seismic energy upto some extent. Types of seismic dampers are: Energy is utilizes by the silicone based fluids passing between piston cylinder. Energy is utilizes by the distortion of metal compounds within the limit Friction Dampers: Energy is utilizes by frictional forces to dissipate energy Viscoelastic Dampers: Energy is utilizes by the controlled shearing of solids IS Codes for earthquake resistant design:

Chapter 7 : National Information Centre of Earthquake Engineering - IIT-Kanpur-INDIA

The purpose of this course is to familiarize the engineer with the basic principles of earthquake-resistant design for residential construction. Adequate construction is required in order for a structure to fair well during and after an earthquake.

Therefore, the Buildings must be built in such a way that they are safe during such occurrence. This has been revised taking care of the experiences of several Earthquakes, which occurred after when the code was last revised. During various Earthquakes, large number of buildings failed and many lessons are learnt especially after Gujrat Earthquake This paper describes in brief the phenomenon of Earthquakes, various provisions that can be made for calculating the Design forces. The Core of Earth is very hot. These currents cause the Crust and a portion of the Mantle to slide over the outer Core. It also gives rise to the development of strain energy, which causes crust to slide over mantle. As a result of such movements, strains are building up at plate interfaces. In course of time, when this cumulative strain energy becomes excessive for the rock plates to sustain, it gets released in the form of a slip occurring between adjoining plates. The interface of plates is called fault or fault zones. Some of these faults are active, whereas others are not. There are many other explanations about the occurrence of earthquakes. Tsunami When the epicenter of earthquake is on Sea floor, then vibrations are also caused on the body of seawater. Therefore, earthquakes on sea floor are the origin of tsunami waves. After an earthquake has occurred beneath the sea floor at shallow depth, it takes some time say few minutes to few hours for dynamic waves of large heights to be formed. The shock embedded wave travels at a speed of about km per hour or so and reaches Coastline. At this point, the first rupture of the fault surface takes place. The point right above the focus is called the Epicenter as shown in Figure The magnitude of an earthquake is the measure of the energy released from the Focus. By definition, Magnitude is the logarithm to the base 10 of the maximum trace amplitude, measured in microns m , which the Standard Short Period Torsion Wood â€” Anderson Seismometer would register due to the earthquake at an epicentral distance of km. It is seen from above relation that energy released by an earthquake increases by a factor of 32 for each unit increase in magnitude. That is, each increase in magnitude number is a 10 â€” fold bigger wave and has 32 â€” fold increase in energy released by that wave. It is said that Bhuj Earthquake at magnitude 7. The magnitude of earthquake by itself is not sufficient to indicate whether Structural damage at any place can be expected. This is only a measure of the size of earthquake and energy released at its source. This is a measure of damage occurred to a structure and is defined by Modified Mercalli Scale. The intensities are classified on 12 level scales in IS: In this revision, Zone I has been eliminated. Structural response affecting the buildings is described here. A typical response of any building during an Earthquake is shown in Figure â€” 4 a. During an earthquake, amplitude of vibration generally buildup in a few cycles. A typical diagram showing the amplitude build up of any object during few cycles of earthquake excitations Fig. It is to be noted that RC framed buildings during Latur Earthquake suffered less damage as compared to the Gujrat Earthquake. Earthquakes cause motion to the ground in random direction. The amplitude of motion of any structure normally builds up over a period of time in a few cycles i. Thus, if the Earthquake lasts longer, the amplitude of vibration is more, i. The violent ground motion pushes the building rapidly from one direction to another making it difficult for the super-structure to constantly balance its load due to inertial effects. A superstructure can be damaged, not only on account of the shaking which results from quakes but also due to chain effects like fire, land slide etc caused by earthquake. There are two essential features to make a building earthquake resistant i. To achieve this, the desirable factors required in design of any structure for better Earthquake resistance are: Thus, it is desirable that the material used for construction is ductile, especially at locations where damage is expected like at Beam-Column junction. Normally Reinforced Concrete is a good ductile material. The safest building will be the one made of all steel though very heavy â€” attracting more earthquake force , as it is an extremely strong material. Reinforced Concrete is the next most suitable material for earthquake resistant construction of buildings. It is a good, durable and economic material of construction, but the condition is that the quality of construction should be good. It was seen during the Latur earthquake, that most buildings made with concrete, remained standing without suffering much damage. But during the Gujrat earthquake many buildings made in RCC also got damaged or collapsed because of poor quality of construction. B Other Materials A brick, stone or mud house cracks even with moderate tremors. However, these materials can be effective when strengthened with RCC elements at critical points. Masonry buildings become brittle when large deflections take place, so RCC bands can strengthen them at regular intervals. A wooden frame building is good as it absorbs shock evenly and vibrates along the quake and unlikely to collapse. The danger with wooden frame structures is that it is highly inflammable and has limited use i. In the design of buildings, horizontal force due to earthquake is considered simultaneously along with the vertical forces. Normally, the natural period of vibration of any structure should not coincide with the predominant period of earthquake excitations, otherwise resonance may occur and even the strongest structure may collapse. Thus, while designing the building, following aspects should be looked into: Response of Structure to earthquake Design forces, to which the building elements will be subjected, can be calculated by any one of the following methods. Seismic Coefficient Method 2. Response Spectrum Method Modal Analysis 3. Depending upon the complexity and importance of Structure, any one of the above three methods can be adopted. Here only seismic coefficient method is described, as this is the most common method. Earthquake forces can be calculated in any direction of Structure, but the most damaging direction is horizontal Least lateral direction. The horizontal earthquake force can be calculated as: Here description of various parameters is given below. These values are given in table 1 as per revised code. The factor 2 in the denominator of Z is used so as to reduce the maximum considered earthquake MCE zone factor to the factor for design basic earthquake factor DBE.

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Chapter 8 : Earthquake engineering - Wikipedia

Earthquake engineering is an interdisciplinary branch of engineering that designs and analyzes structures, such as buildings and bridges, with earthquakes in mind. Its overall goal is to make such structures more resistant to earthquakes.

The answer is yes and no. There are of course, engineering techniques that can be used to create a very sound structure that will endure a modest or even strong quake. However, during a very strong earthquake, even the best engineered building may suffer severe damage. Engineers design buildings to withstand as much sideways motion as possible in order to minimize damage to the structure and give the occupants time to get out safely. Buildings are basically designed to support a vertical load in order to support the walls, roof and all the stuff inside to keep them standing. Earthquakes present a lateral, or sideways, load to the building structure that is a bit more complicated to account for. One way to to make a simple structure more resistant to these lateral forces is to tie the walls, floor, roof, and foundations into a rigid box that holds together when shaken by a quake. The most dangerous building construction, from an earthquake point of view, is unreinforced brick or concrete block. Generally, this type of construction has walls that are made of bricks stacked on top of each other and held together with mortar. The roof is laid across the top. The weight of the roof is carried straight down through the wall to the foundation. When this type of construction is subject to a lateral force from an earthquake the walls tip over or crumble and the roof falls in like a house of cards. Construction techniques can have a huge impact on the death toll from earthquakes. The difference in those death tolls comes from building construction and technology. In Haiti, the buildings were constructed quickly and cheaply. Chile, a richer and more industrialized nation, adheres to more stringent building codes. Acting like shock absorbers in a car, these systems allow the building to be decoupled from the shaking of the ground. Watch the video below to see these system in action. In the event of a major earthquake, they can sway up to a few feet. Another technique to dampen the swaying of a tall building is to build in a large several tons mass that can sway at the top of the building in opposition to the building sway. Weighing in at tons and capable of moving 5ft in any direction, it takes the prize as the worlds largest and heaviest building damper. In fact, it is so heavy that it had to be constructed on site since it is to heavy to be lifted by a crane. Can you build a better building? Here is a great video from WIRED that shows how a large shake platform can be used to test a full-scale structure in response to the motion of an earthquake. I love the crazy shot at 1:

Chapter 9 : Earthquake engineering Facts for Kids

However, it is possible during your design and construction process to build in a number of earthquake resistant features by applying earthquake engineering techniques, which would increase enormously the chances of survival of both buildings and their occupants.