A Review of Building Configuration Requirements
In
International Seismic Regulations

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Contents

1. Introduction

Introduction

The top priority of most seismic regulations is to protect life, and this means retaining structural integrity of the building, during and after the shaking. Seismic building regulations are designed to ensure new buildings possess a certain level of resistance against seismic movement. The regulations aim to improve the performance of buildings in earthquake events, and to limit damage to an acceptable level.

Building configuration has a significant effect on the behaviour of a building in an earthquake. It is well documented that buildings with simple and regular configurations generally perform better than those with complicated or irregular configuration. Also, the understanding of simple structures is better, so predictions of their behaviour in an earthquake are more accurate.

The basic configuration of a building determines what type of resisting system will be used, and generally, how effective it will be. Often, when there is collapse, it is due to a major flaw in the configuration, even with the careful design of individual structural elements within the building.

Developing Countries

Developing, or third world countries, commonly have a lower standard of design and construction of buildings. This is partly due to a lack of educated and skilled people, as well as the society being too poor to afford better construction types and materials. The recent catastrophic damage to buildings in Turkey, India and Central America caused by earthquakes demonstrates the importance of this problem. Such countries often do not have the expertise available to design earthquake resistant buildings. Simply increasing the strength requirements in the regulations would not solve this issue, as they cannot afford to build stronger buildings. However, limiting the choice in design of form to good, simple, regular configuration within the local building regulations, can significantly reduce any unexpected stresses induced upon a structure, and hence, reduce the need for specialist analysis, and lead, ultimately, to improved seismic performance.

The Aim of This Report

The aim of this report is to review international seismic building regulations to show what areas of building configuration code requirements are well covered, inadequately covered, and what countries are leaders in providing safe building configuration regulations.

2. Method

Introduction

This chapter provides an explanation of the method used to carry out this research. As such, it describes the scoring system used as the basis for evaluating the different countries seismic building regulations.

Selection of Method

It was decided that the easiest technique for dealing with the information gathered from all the regulations was to enter it into a database. This way the information can be easily re-organised to suit any question being asked. The majority of regulations were found in the International Association of Earthquake Engineering publication Earthquake Resistant Regulations A World List. This is published every four years and contains the most recent earthquake regulations.

A grading system was developed, in order that a numerical comparison could be made between the content of the clauses within each of the building regulations. This made it easier to comment on their effectiveness for each of the aspects of configuration being studied.

Method

As many international seismic building regulations were looked at as possible, within the time period of this study. The most current regulations available were used. Thirty-three countries' seismic building regulations were included in this study. An alphabetical list of all the countries and regulations can be found in Appendix A. Appendix B has all the relevant information taken from each of the regulations.

Sections and clauses on building configuration and structural regularity were found and entered into the database. The following headings were used to sort and order the data:

- Country
- Year of publication used in this report
- Year of Current Regulation
- Title of Regulation
- Horizontal Regularity
- Vertical Regularity
- Analysis

It was then decided whether the country was considered developing or developed, for a later comparison between codes of developing and developed countries to find any trends.

Grading System

A grading system was developed to provide a numerical comparison between the information gathered from each country's regulations. The rating scale, related to the comprehensiveness of the configurational regulations was valued as follows.

Score 0: Not Mentioned, (therefore allowed).
This means there was no specific mention of the configuration problem under study within this regulation.

Score 1: Mentioned; the configuration problem is to be kept to a minimum.
The problem was specifically mentioned, but the regulation only states it to be reduced if and where possible. For example, the irregularity might have been identified as a problem, but no limitations have been placed on it, as in the case of the Chinese Building Design Code. It states in a clause dealing with uniform mass distribution:
"...the [building's] weight and stiffness should be uniformly distributed." [3]

Score 2: Allowed, with conditions attached.
This means that the irregularity is allowed if it is kept under a particular value or within certain limits. The irregularity has been recognised as a problem and limitations are necessary. For example, the Mexican Technical Norm says of re-entrant corners:
"The plan shall not have protruding or re-entrant portions with dimensions larger than 20% of the plan dimension measured parallel to the direction of the protruding portion or re-entrance considered." [3]

Score 3: Allowed, provided a dynamic analysis is undertaken.
This means that the irregularity is allowed if a more complicated and precise analysis is done to prove the building will still perform adequately. The regulation recognises the problem and tries to ensure the building will perform adequately in spite of it. This is shown in the New Zealand Standard 4203:1992:
"A three-dimensional modal analysis or a three-dimensional numerical integration time history analysis shall be used for structures which do no comply with 4.3.2 and which do not satisfy the horizontal regularity requirements of 4.4.1." [5]

Score 4: Allowed, with conditions together with a dynamic analysis.
This means that the irregularity is allowed if it is kept within certain limitations, and a more complicated and precise analysis is done. The irregularity is seen as a significant problem, and steps have been taken to ensure buildings having this condition are safe. The Uniform Building Code of the United States of America illustrates this:
"The dynamic lateral-force procedure shall be used for all other structures, including the following:

1. Structures 72.152 m or more in height, except as permitted by section 1629.8.3 item 1.
2. Structures having a stiffness, weight or geometric vertical irregularity of type 1, 2, or 3, as defined in Table 16-L, or structure having irregular features not described in Table 16-L or 16-M, except as permitted by section 1630.4.2." [4]

Score 5: Not allowed.
The irregularity is not allowed in any building under any circumstances. The problem is seen as too great a risk to buildings being built with it. German Standard DIN 4149 requires this:
"The following must be avoided:
a) Walls which do not pass uninterruptedly through all the stories, or walls with large cut-outs, which result in great differences in the uniformity of the rigidity over the height." [3]

It is important to note that four could be the most desired score as it allows buildings to have interesting, or unusual designs, as long as they are proved to be safe. If a regulation scored all fives, all the buildings in that country would be solid boxes, with little architectural freedom.

The rating scale was used to evaluate the building regulations under each of the following building configuration irregularities:
Horizontal:
- Asymmetrical Plan
- Non-uniform Mass Distribution
- Re-entrant Corners
- Diaphragm discontinuity

Vertical:
- Change in Strength
- Change in Stiffness
- Discontinuity of Vertical Elements
- Setbacks

These irregularities are identified and described in Chapter 3.

<u>Analysis</u>
The rating scale shows clearly which regulations are lacking, in what areas, and which regulations cover each area of irregularity sufficiently. The total score shows how well a regulation covers configuration generally. Averages of the scores for each of the irregularities are taken to assess which are best covered, and which ones are inadequately provided for, over all the countries.

Results are analysed for any trends over time, and between developing and developed countries, by graphing the scores of the regulations by the year they were published.

Problems and Areas of Uncertainty

Unfortunately, not every current regulation was available for this study. Five countries have a more recent regulation than was used in this report: Australia, Canada, Greece, Mexico, and Romania. This creates uncertainty in the results, as the new regulations are more likely to include more detailed descriptions of building configuration and regularity due to growing understanding of this subject. The standard of English in some of the regulations was low due to poor translation, and the intent of the original regulation may have been lost.

Conclusion

This chapter has discussed the research method for this study. It describes the grading system to explain the results found later in the report, and identifies the headings under which the irregularities are going to be graded.

3. Building Configuration

Introduction

Configuration of buildings is defined as the overall shape of the building, the size, nature and locations of resisting elements and non-structural members that effect building performance. Configuration, to a large extent, determines *where* damage is likely to occur[1]. Putting limits on poor configuration can control building damage, by controlling failure modes.

An architect influences the seismic performance of buildings, by determining the basic configuration at an early design stage. The architect decides, or at least influences, the type of resistance system used, and how effective it will be. This does not mean detailed engineering design of structure cannot overcome some of these issues. With careful analysis, elements can be designed to resist loads placed upon them. However, poor configuration can often induce larger stresses in an element than what has been designed for. Many failures that have resulted in structural collapse are generated from poor configuration [1].

What factors contribute to poor configuration?

<u>Asymmetry in Plan</u>

Structural symmetry in plan means that the centre of mass and the centre of resistance are located at the same point. Asymmetry produces eccentricity between the centre of mass and the centre of rigidity, which results in torsion. Torsion effects can be very destructive and can be hard to assess properly [2]. Asymmetry can lead to stress concentrations that cannot be known and therefore are not included in the analysis of the building. It is best to have symmetry in both directions. (Symmetry in elevation is of less significance to building performance in an earthquake than plan symmetry[1].)

<u>Non-uniform Mass Distribution</u>

Torsion can also result from other non-symmetry factors, such as variations in weight distribution. It is best to have the mass of the building uniformly distributed over the plan. This provides better internal loading conditions. A building has greater chance of surviving an earthquake if load-bearing members are uniformly distributed[2]. This refers to all structural elements within the building as well, not just the overall building shape. For example, locations of cores, shear walls etc. It is best to uniformly and continuously distribute strength throughout the structure. This way there are more members and joints to share the load. Having more resistance around the perimeter increases the resisting moments that can be generated against overturning and torsion.

Re-entrant Corner

Re-entrant corners produce stress concentrations at the notches in floor diaphragms due to indirect load transfer. Re-entrant corners can cause severe damage at the notch area by the two wings pounding against each other as they move differently in the shaking.

A building with re-entrant corners can have a symmetrical plan, such as an H, or a crucifix plan. This shows that symmetry is not enough in itself, but needs to be combined with simplicity. Arnold describes simplicity as when it is possible to connect any two points within the shape by a line that does not cross the shape's boundary as shown in Figure 1.

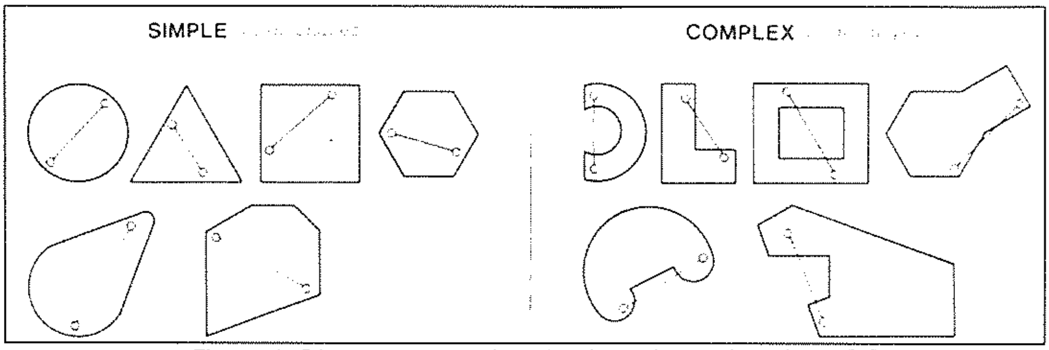


Figure 1. Diagram comparing simple and complex plans. [1]

T, I, L and H section shape produce torsion. The effect of re-entrant corners on a building's performance depends the length and heights of the wings. If a regular plan is not appropriate for an aesthetic reason, it is better to create two regular plan structures with movement gaps between.

Diaphragm Discontinuity

Large holes or discontinuities in diaphragms significantly weaken their ability to transfer loads to resisting members. The discontinuities also create variations in stiffness across the plan of the buildings, which can increase torsion.

Discontinuity of Vertical Elements

All columns and walls should be vertically continuous throughout the building. This configuration transmits loads as directly and efficiently as possible. To interrupt this load path is a fundamental error[1]. When vertical elements are missing from a level, it increases stress on horizontal members who have to transfer loads from the vertical member above to the vertical member below. This stress may not have been designed for in the horizontal element. Discontinuities in shear walls can cause significant problems, as they cannot collect diaphragm loads at each floor.

Change in Strength

Changing the strength up the height of the building can create weak storeys. This occurs if one inter-story height is significantly taller than those adjacent to it, or if vertical members are not continuous. The majority of the earthquake energy will be concentrated in the weaker floor or at points of discontinuity, instead of being more uniformly distributed among all the storeys. This load concentration will create more structural deformity than on the other floors.

Change in Stiffness
Changes in stiffness up the height of a building can create soft storeys. Within a soft storey, the deflection will be much greater than that of other floors, and hence this floor will experience more stress and damage. Often this happens at ground level, with a taller inter-storey height, or fewer columns. This is the worst possible scenario as gravity forces on the building are greater towards the base of a building due to the weight of the storeys above. Soft and weak storeys are often at ground level, but still cause huge problems anywhere in the building.

Setbacks
This is a very common occurrence in buildings. It causes a problem by creating discontinuities in stiffness and in strength up the height of the building. Problems are most likely to occur at the notch, which can be thought of as a vertical re-entrant corner. The seriousness of this irregularity depends on the proportions, as well as the symmetry or asymmetry in the plan of the tower and base. It is important to continue vertical elements through from the tower to the base, to the foundations or the problems mentioned above will again occur.

Conclusion
Horizontal irregularities can create huge torsion stresses in the building. However, vertical irregularities are often far more serious, as they can lead to complete collapse of the building. Vertical elements collapsing due to unexpected load is more dangerous than horizontal members as it increases the load tremendously on whatever members are left. If they cannot hold the weight of the building above, it will cause structural collapse.

4. Results

Introduction

This chapter provides the results from applying the grading system as explained in Chapter 2, to thirty-three countries' seismic building regulations. The results are divided into three sections; horizontal irregularity, vertical irregularity and the combined score for both.

Horizontal Irregularities in Building Configuration

Table 1. Results of Horizontal Regularity Score

Country	Year	Developing	Asymmetrical Plan	Non-uniform Mass Distribution	Re-entrant Corners	Diaphragm Discontinuity	Total
Austria	1961	no	1	1	0	0	2
Cuba	1964	yes	0	0	0	1	1
Peru	1977	yes	1	1	0	0	2
Australia	1979	no	1	1	0	0	2
Germany	1981	no	5	5	0	0	10
Romania	1981	yes	5	5	0	0	10
Yugoslavia	1981	yes	5	1	0	0	6
Venezuela	1982	no	4	4	0	4	12
Ethiopia	1983	yes	3	3	3	0	9
Indonesia	1983	yes	3	3	3	0	9
Portugal	1983	no	1	1	0	0	2
Greece	1984	no	1	0	0	1	2
India	1984	yes	3	3	0	0	6
Costa Rica	1986	yes	5	5	0	0	10
Bulgaria	1987	no	2	2	0	0	4
Mexico	1987	yes	5	5	2	2	14
Egypt	1988	yes	3	1	3	0	7
Iran	1988	yes	4	4	0	0	8
Korea	1988	no	0	4	4	4	12
China	1989	yes	3	1	0	0	4
Switzerland	1989	no	4	4	0	4	12
Canada	1990	no	3	3	0	0	6
France	1990	no	3	3	0	0	6
Japan	1992	no	0	3	0	0	3
New Zealand	1992	no	3	4	0	4	11
Philippines	1992	yes	4	4	5	0	13
Europe	1994	no	2	2	0	0	4
Israel	1995	yes	4	4	0	2	10
Nepal	1995	yes	3	3	5	0	11
Chile	1996	no	1	0	0	1	2
USA	1997	no	4	4	4	4	16
Columbia	1998	yes	4	4	4	4	16
Turkey	1998	yes	4	4	4	4	16
Panama	1998	yes	4	4	4	4	16
Average			2.85	2.79	1.12	1.06	7.82

Asymmetry in Plan

Asymmetry in plan was generally well covered, with only three out of the thirty-three countries failing to acknowledge it as a problem. It has the highest average score of the four horizontal irregularities, at 2.85. Germany, Romania, Yugoslavia, Mexico and Costa Rica all do not allow asymmetrical planned buildings to be built. This is illustrated in the Yugoslavian regulation:

"Suitable layout of the load bearing structures of buildings shall be achieved by means of a regular and simple floor-plan arrangement, with a uniform distribution of masses." [3]

Many regulations acknowledge the problem and state that buildings should be regular or simple, and where this is undesirable, seismic joints should divide the building into separated parts. Eurocode 8 states:

"Structures should have simple and regular forms both in plan and elevation. If necessary this may be realised by subdividing the structure by joints into dynamically independent units." [4]

Developing countries had a higher average score in this area compared to developed countries: 3.5 compared to 2.19. This will be discussed in Chapter 5.

Mass Distribution

Uniform mass distribution was also generally well covered, again with only three countries failing to mention this irregularity. Many countries combined symmetry and mass distribution irregularities in the same clause, as France does:

" The plane construction shape, as well as the distribution of masses and stiffnesses along the height, must verify the regularity conditions indicated in part V." [3]

For this reason, the average scores for asymmetrical plan and mass distribution are similar.

Re-entrant Corners

Twenty-five countries did not specifically mention re-entrant corners. It had the lowest average score of any of the horizontal irregularities. Of those countries that did include the irregularity, the average was 3.8, which is very high. This suggests the countries that are aware of the problem believe it to be significant. The Philippines specifically mention re-entrant corners:

"Re-entrant angles in the plan shape of a structure should be avoided. Where this is not feasible and the length of the wings exceed one-quarter the width of the core section of the structure, the structure shall be treated as highly irregular." [4]

The American Uniform Building Code allows re-entrant corners if they remain under a certain limit, otherwise the building is considered irregular and needs specific analysis to comply:

"Plan configuration of a structure and its lateral-force-resisting system contain re-entrant corners, where both projections of the structure beyond a re-entrant corner are greater then 15% of the plan dimension of the structure in the given direction." [4]

Diaphragm Discontinuity

Diaphragm discontinuity was not very satisfactorily covered, with twenty-one of the regulations not mentioning it at all. The Greek regulation mentions 'plates' but with no limitations or restrictions:

"...the strength of the plate at the differential points of the sectional plan and especially of the weakest should be considered." [3]

Omitting limitations renders the clause ineffectual. It is covered better in the Korean regulation, where, if the discontinuity is over a certain amount, the building is considered irregular and it requires specialist analysis. The following is a description of irregular:

"Diaphragms with abrupt discontinuities or variations in stiffness, including those having cut-out or open areas greater than 50% of the gross enclosed area of the diaphragm, or changes in effective diaphragm stiffness of more than 50% from one story to the next." [3]

Developed countries had a better response to this irregularity with an average score of >1.0, than developing countries, with an average score of <1.0. The overall average of 1.0 is a very score for this irregularity.

Horizontal Irregularity Overall

Most countries had some mention of horizontal irregularity, but failed to specifically describe the different types. The lowest score was the regulation from Cuba, which made no specific mention of regularity or simplicity. The highest score of 16 was shared by four countries; Turkey, Columbia, Panama and the United States of America. (The first three countries listed have their regulations based on the American code). These four codes all mentioned each of these irregularities and had limitations placed upon them that when exceed dynamic analysis became necessary. The New Zealand Standard scored 11 (out of a possible 20). It failed to mention re-entrant corners.

Although there is a wide variation in the regulations' scores of horizontal regularity, it can be seen that over time the standard has increased. The trend line in Figure 1 illustrates this.

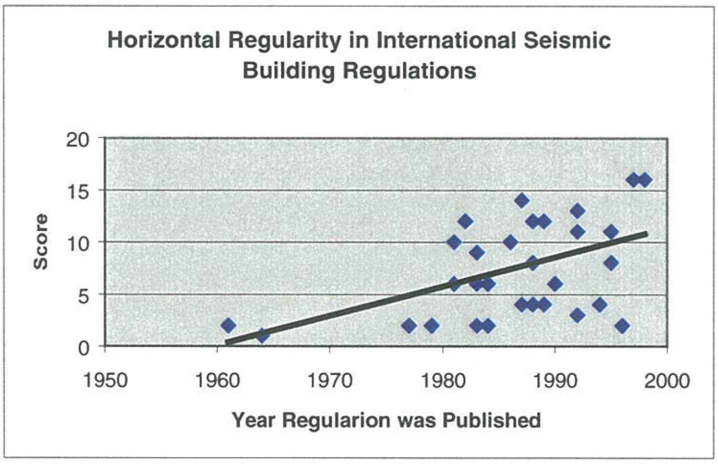


Figure 2. Graph of Horizontal Regularity Scores versus the Year Published

Vertical Irregularity in Building Configuration

Table 2. Results of Vertical Regularity Score

Country	Year	Developing	Change in Strength	Change in Stiffness	Discontinuity of Vertical Elements	Setbacks	Total
Austria	1961	no	0	0	0	4	4
Cuba	1964	yes	0	0	0	0	0
Peru	1977	yes	3	3	3	3	12
Australia	1979	no	0	0	0	4	4
Germany	1981	no	0	0	5	0	5
Romania	1981	yes	0	0	5	1	6
Yugoslavia	1981	yes	3	3	0	2	8
Venezuela	1982	no	4	4	4	4	16
Ethiopia	1983	yes	3	3	0	4	10
Indonesia	1983	yes	4	4	0	4	12
Portugal	1983	no	1	1	0	0	2
Greece	1984	no	0	0	3	2	5
India	1984	yes	3	3	0	0	6
Costa Rica	1986	yes	3	4	4	4	17
Bulgaria	1987	no	5	5	0	0	10
Mexico	1987	yes	2	2	0	0	4
Egypt	1988	yes	3	3	0	4	10
Iran	1988	yes	4	4	5	5	18
Korea	1988	no	4	4	0	4	12
China	1989	yes	4	4	0	0	8
Switzerland	1989	no	3	3	3	3	12
Canada	1990	no	3	3	2	2	10
France	1990	no	4	4	5	0	13
Japan	1992	no	4	4	0	0	8
New Zealand	1992	no	3	3	0	0	6
Philippines	1992	yes	0	4	0	4	12
Europe	1994	no	3	3	0	4	10
Israel	1995	no	4	4	4	4	16
Nepal	1995	yes	3	3	0	3	9
Chile	1996	yes	0	2	0	0	2
USA	1997	no	4	4	4	4	16
Columbia	1998	yes	4	4	4	0	12
Turkey	1998	yes	4	4	4	0	12
Panama	1998	yes	4	4	4	4	16
Average			2.58	2.79	1.67	2.09	9.30

Change in Strength and Stiffness

Most of the countries that had sections on changing the strength and stiffness had one clause for both. This explains why the averages for these two irregularities are so similar. This is exemplified in the Egyptian regulation:

"The distribution of horizontal seismic forces in major buildings that have highly irregular shapes, large differences in lateral resistance or stiffness between stories, or other unusual structural features shall be determined in accordance with the dynamic analysis procedure." [3]

Some codes, such as the Columbian regulation below, had separate definitions or what was considered irregular for the change in strength and change in stiffness.

"1P Flexible Story (Irregularity in Rigidity)

When the rigidity in front of horizontal forces of a story is lesser than 70 % of the superior story rigidity or lesser than 80% of the average of three superior stories rigidity, the structure shall be considered irregular.

5P Soft Story -Discontinuity in the Resistance

When the story resistance is lesser than 70% of the immediately upper story, inside of the action plane, greater than the horizontal dimension of the element, the structure shall be considered irregular." [4]

This is a preferable as it gives more detailed information on what is considered an irregular building.

Developing countries outscored developed countries in both stiffness and strength in the average score, but a smaller percentage of developing countries actually mentioned this irregularity. This means that the developing countries that did include these irregularities covered them well.

<u>Discontinuity of Vertical Elements</u>

This irregularity is possibly the most dangerous, as it creates such large forces in elements of the building that were not designed for them. It was inadequately covered overall, with 19 countries not mentioning it at all. The average score was 1.67. The French regulation disallowed discontinuity completely:

"The structure may not include any vertical bearing element whose load is not transmitted along a direct line to the foundation."

In other regulations, if vertical discontinuity is present there has to be dynamic analysis done in order to comply. This is the case in the Turkey code where the following is considered irregular:

"B3: Discontinuity of Vertical Structural Elements:

The case where vertical structural element (columns or structural walls) are removed at some stories and supported by beams or gusseted columns underneath, or the structural walls of upper stories are supported by columns or beams underneath." [4]

It also has diagrams to illustrate its descriptions of vertical irregularity.

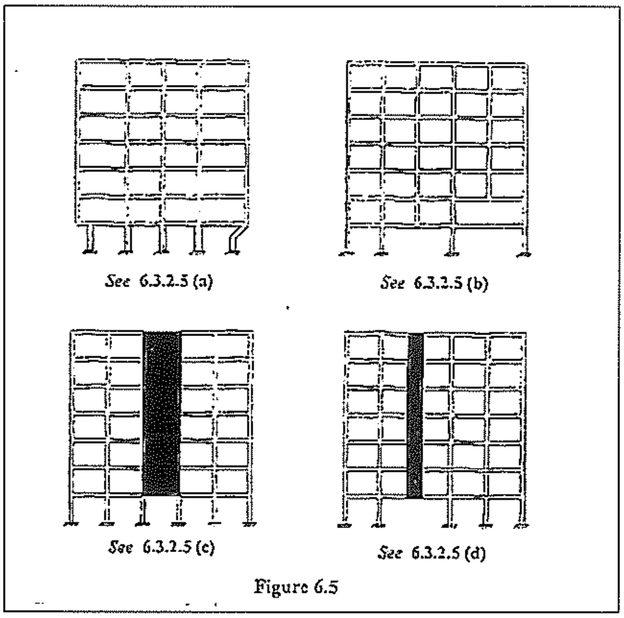


Figure 3. Vertical Irregularity Diagrams from Specifications for Structures to be Built in Disaster Areas (part III) Earthquake Disaster Prevention, from Turkey. [4]

Setbacks

Setbacks were mentioned in most codes, but only sixteen out of the thirty-three countries placed limitations on the condition. This results in the low average score of this irregularity. Most codes allow for it if the condition is kept under certain restrictions. The Peruvian regulation provides limitations, which if surpassed, changes are required to the method of calculating the forces;

"If the reduced dimension in plan is not less than 3/4 parts of the dimension of the immediate lower story in the direction in which the earthquake is considered, the force H shall be calculated and shall be distributed in height according to the specification in 1.14. Similarly if the base of the building with reduction has the height less or equal to 30% of the total height of the building, it shall be considered that the reduction will not modify the distribution of H force." [3]

The average score for developed and developing countries was very similar.

Vertical Irregularity Overall

In general the vertical irregularity factors were not as well covered as the horizontal. However, the average score over all the countries for all four vertical irregularities was higher than that of the horizontal. This discrepancy suggests that the countries that did recognise the problem believed them to be serious.

The lowest score was Cuba, with zero, whose code failed to mention any regularity concerns in elevation. The highest score of 18 was given to Iran whose code was very strict in not allowing these irregularities. The average score for developing countries was marginally higher than for developed countries. The highest score for developed countries was 16, achieved by America, Israel and Venezuela.

When comparing these scores to the year the regulations were published, it was seen that the overall trend has been for an improved level of regulation as new regulations have been introduced. This is illustrated in Figure 3 below with a solid trend line.

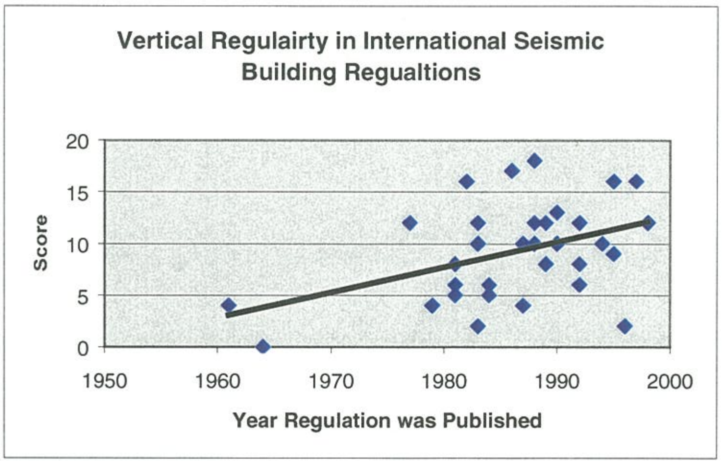


Figure 4. Graph of Vertical Regularity Scores versus the Year Published

Combined Scores, both Horizontal and Vertical

From a total possible score of forty, only two countries gained over thirty, the United States of America and Panama. The Panama code is based on the America code. The average score for all countries was 17.32, well below fifty percent of the maximum value attainable.

Countries that scored well were Turkey, Columbia and Venezuela, who all scored 28. (It is important to note that the Turkish and Columbian regulations are also based on the American code as well.) After these countries, Iran scored 26, the Philippines scored 25, and Korea, Switzerland and Israel all scored 24. New Zealand was well behind these countries scoring only 17, below the average for all countries. This low score is mainly due to the standard not mentioning setbacks or discontinuous vertical elements.

The difference between developing and developed countries' regulations was not as distinct as was expected. The possible reasons for this are discussed in Chapter 5. Figure 4 shows that there is no obvious trend between the two categories of countries in regards to building configuration in their regulations. This is seen in the closeness of the two trend lines.

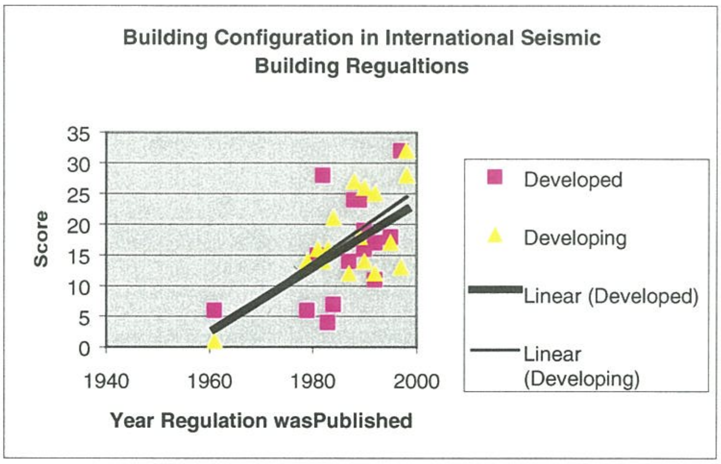


Figure 5. Graph of Regularity Scores versus the Year Published for both Developing and Developed Countries

Conclusion

As would be expected with increasing knowledge in this area, these results show an obvious trend for improvement of building regulations with time. However, the results did not show a difference between developing and developed countries.

All the results in this chapter were found by applying the method described in Chapter 2. Discussion of their implications is given in the following chapter.

5. Conclusion

Introduction

This chapter includes discussion and conclusions from the results of Chapter 4. It comments on horizontal and vertical regularity, developed and developing countries, and the New Zealand Standard.

Horizontal Regularity

Horizontal irregularities were well covered overall. Nearly all the countries, 91 %, mentioned symmetry in plan and uniform mass distribution. This shows that the problem is well recognised and precautions have been taken against it. However, a significant number of countries suggest keeping asymmetry in plan and mass to a minimum, without any actual restrictions placed on the condition. This renders the clauses fairly ineffectual. This is the case for Austria, Cuba, Peru, Australia, Portugal, Greece, and Chile. A few countries disallow irregular plan and mass distribution, such as Germany, Romania, Yugoslavia and Costa Rica. This is reasonably drastic, but separating the building into regular portions with movement joints can alleviate the problem. This method of dealing with these irregularities has been taken by several countries, and should be reviewed for inclusion in the countries that scored low in this category.

Re-entrant corners and Diaphragm discontinuity were covered well by the countries that included them, but unfortunately many countries omitted describing these irregularities at all. Twenty-five of the countries studied neglected to mention re-entrant corners, and twenty-one failed to include any section on diaphragm discontinuity.

These two problems have been well documented as causing large amounts of damage and should be included in seismic building codes. Some countries included these irregularities in a general horizontal regularity clause, but it is felt that the problems need to be specifically mentioned to increase understanding of what constitutes an irregular building. Many designers would be unaware of some of these issues. The American Uniform Building Code has a comprehensive description for both of these conditions and is a recommended precedent for other codes to follow.

Vertical Regularity

Fewer countries covered vertical irregularity issues as well as they did for horizontal irregularities. This is not shown in the average score however, which is noticeably higher. The countries that did acknowledge these problems considered them to be significant enough to warrant limitations. Six countries did not mention changes in strength and stiffness over the height of the building: Austria, Cuba, Australia, Germany, Romania, and Greece. This irregularity needs to be included in seismic regulations as it can cause such extreme damage to buildings.

A section on setbacks was included in most regulations - twenty out of the thirty-three. Only Iran restricted the use of them completely. Most countries recognised that with careful design, and limitations on the extent of the setback, the problem can be controlled to an acceptable extent.

Discontinuity of vertical elements is a serious problem that needs to be addressed in building regulations. It can create large, unexpected stresses on other members, and create variations in stiffness and strength up the height of the building. Nineteen countries failed to mention this irregularity, including New Zealand. A simple clause such as that in the French regulation could be included to stop this irregularity occurring:

"The structure may not include any vertical bearing element whose load is not transmitted along a direct line to the foundation."

However, this is very restrictive and would not allow any architectural freedom. A more detailed description of the irregularity could be included, so the problem can be recognised and designed for, such as in the American regulation that considers the following to be irregular:

"In-plane discontinuity in vertical lateral-force-resisting element
An in-plane offset of the lateral-load-resisting elements greater than the length of those elements."

Developing and Developed Countries

There was not the expected difference between developing and developed countries. This could be due to several reasons; the first being the average age of the two groups' regulations. The average publication date for developing countries was a year higher than that for developed countries. From the results, it is known that the regulations' score increased with the year published. This is mainly due to three countries, Columbia, Turkey, and Panama, all publishing new regulations in 1998, after the American Uniform Building Code was produced. It can be seen from the high scores of these three countries that it was a successful move to base their regulations on such a comprehensive code. From this example it is suggested that other countries that may lack the resources and technical expertise to develop adequate building regulations for themselves, should base their regulations on successful documents from overseas. The American code had the best score in this study and would be a good basis for other countries to start from. However, it requires expertise, which some developing countries may not have, to prove buildings fully comply with all conditions.

The New Zealand Regulation

The New Zealand standard 4203:1992 scored below average for all countries. This score could be improved dramatically be including a few simple clauses illustrating what conditions are considered irregular. The only vertical regularity section stated:

"To satisfy the vertical regularity requirements for the use of the equivalent static method, the lateral displacement of each level shall be reasonably proportional to its height above the base."

This should include some comments on variations in strength and stiffness, and the discontinuity of vertical elements as well. It should also include a definition for 'reasonably'.

Work for a future updated publication is currently being done on this standard,.

Summary

Overall, the codes scored poorly in horizontal and vertical regularity. However, they scored higher the more recent they are. This suggests that the problems linked with irregular building configuration are being recognised and slowly being included in building regulations. It is important for countries to maintain a regular updating system so new findings, from within their country and abroad, can be incorporated into existing regulations.

For countries without resources or expertise in this area, it is beneficial to base their regulations on a regulation of a more advanced country, adapting it to suit their conditions.

The New Zealand Standard "Code of Practice for General Structural Design and Design Loadings for Buildings NZS 4203:1992" was found to be lacking in adequately describing and limiting building configuration irregularities.

References

[1]. Arnold, Christopher. Reitherman, Robert. Building Configuration and Seismic Design. 1982. John Wiley and Sons, Inc.
[2]. Dowrick, David J. Earthquake Resistant Design For Engineers and Architects. 2nd Edition. 1987. John Wiley and Sons, Inc.
[3]. IAEE. Earthquake Resistant Regulations A World List –1992. July 1992. International Association for Earthquake Engineering.
[4]. IAEE. Earthquake Resistant Regulations A World List –2000 Update. July 2000. International Association for Earthquake Engineering.
[5]. NZS 4203: 1992 General Structural Design and Design Loadings for Buildings. 1992. Standards New Zealand.

Appendix A: List of Countries & Regulations

Australia Year: 1979 Current: 1988 Developing: no
Australian Standard 2121-1979, The Design of Earthquake-resistant Buildings

Austria Year: 1961 Current: 1961 Developing: no
Austrian Standards O NORM B4051 Part 1 Design Loads in Buildings, Forces by Earthquakes to Structures Not Vulnerable to Vibrations

Bulgaria Year: 1987 Current: 1987 Developing: no
Bulgarian Code for Design of Buildings and Structures in Seismic Regions

Canada Year: 1990 Current: 1995 Developing: no
National Building Code of Canada

Chile Year: 1996 Current: 1996 Developing: yes
Earthquake Resistance Design of Buildings

China Year: 1989 Current: 1989 Developing: yes
National Standard of People's Republic of China; Aseismic Building Design Code

Columbia Year: 1998 Current: 1998 Developing: yes
NSR-98 Standard Requirements for Buildings

Costa Rica Year: 1986 Current: 1986 Developing: yes
Seismic Code of Costa Rica

Cuba Year: 1964 Current: 1964 Developing: yes
Standards for Structural Design: Seismic Loads

Egypt Year: 1988 Current: 1988 Developing: yes
Regulations for Earthquake

Ethiopia Year: 1983 Current: 1983 Developing: yes
Code of Practise for Loadings, Ethiopia

(Europe) Year: 1994 Current: 1994 Developing: no
Eurocode 8 Design Provision for Earthquake Resistance of Structures ENV 1998-1-1:1994 General Rules: Seismic Actions and General Requirements for Structure ENV 1998-12:1994 General Rules: General Rules for Buildings

France Year: 1990 Current: 1990 Developing: no
AFPS 90 Recommendations for the Reduction of Rules to the Structures and Installations Built in Regions Prone to Earthquakes

Germany Year: 1981 Current: 1981 Developing: no
German Standard DIN 4149 Part 1 Buildings in German Earthquake Zones; Design Loads, Dimensioning, Design and Construction of Conventional Buildings

Greece Year: 1984 Current: 1995 Developing: no
Antiseismic Regulations for Building Construction

India Year: 1984 Current: 1984 Developing: yes
Indian Standard, Criteria for earthquake Resistant Design of Structures

Indonesia Year: 1983 Current: Developing: yes
Indonesian Earthquake Code

Iran Year: 1988 Current: 1988 Developing: yes
Iranian Code for Resistant Design of Buildings

Israel Year: 1995 Current: 1995 Developing: yes
Design Provision for Earthquake Resistance of Structures SI 413 Israel Standard

Japan Year: 1992 Current: 1992 Developing: no
Standards for Aseismic Civil Engineering Constructions, Earthquake-Resistant design Method for Buildings

Korea Year: 1998 Current: 1998 Developing: no
Building Code for Structural Regulations

Mexico Year: 1987 Current: 1995 Developing: yes
Complementary Technical Norms for Earthquake Resistant Design

Nepal Year: 1995 Current: 1995 Developing: yes
Nepal National Building Code, Seismic Design of Buildings in Nepal

New Zealand Year: 1992 Current: 1992 Developing: no
Code of Practice for General Structural Design and Design Loadings for Buildings

Panama Year: 1998 Current: 1998 Developing: yes
Structural Design Regulations for the Republic of Panama

Peru Year: 1977 Current: Developing: yes
Earthquake Resistant Standards, National Regulations of Construction

Philippines Year: 1992 Current: Developing: yes
National Structural Code for Buildings

Portugal Year: 1983 Current: Developing: no
Portuguese Seismic Code

Romania Year: 1981 Current: 1992 Developing: yes
Code for Aseismic Design of Residential, Public, Agricultural and Industrial Buildings

Switzerland Year: 1989 Current: 1992 Developing: no
Swiss Standard SIA 160 Actions on Structures

Turkey Year: 1998 Current: 1998 Developing: yes
Specifications for Structures to be Built in Disaster Areas (part III) Earthquake Disaster Prevention

U.S.A Year: 1997 Current: 1997 Developing: no
Uniform Building Code Volume 2 Division IV Earthquake Design

Venezuela Year: 1982 Current: Developing: no
Regulations for Earthquake Resistance Design

Yugoslavia Year: 1981 Current: Developing: yes
Code for Technical Regulations for the Design and Construction of Buildings in Seismic Regions

Appendix B: Database Entries

Australia

Year: 1979
Title: Australian Standard 2121-1979, The Design of Earthquake-Resistant Buildings
Current: 1993
Developing: no

Horizontal Regularity:
6.5 Horizontal Torsion
Provision shall be made for the increase in shear forces acting on particular elements resulting from the horizontal torsion due to eccentricity between the centre of mass and centre of rigidity.

Vertical Regularity:
6.3.1 Regular Buildings or Framing
For a regular building or framing system the total horizontal forcce shall be distributed over the height.

6.3.2 Setbacks
Where a regular building or framing system has one setback in which the plan dimension of the tower in each direction is at least 0.75 times the corresponding plan dimension of the lower part, such a building may be considered as being without a setback for earthquake analysis.
For regular buildings or framing systems with other conditions of setbacks the tower shall be designed as a separate building.

Analysis:
6.3.3 Irregular Buildings or Framing Systems:
The distribution of horizontal force shall be determined considering the dynamic characteristics of such buildings or systems.

Austria

Year: 1961
Title: Austrian Standards O NORM B4051 Part 1
Design Loads in Buildings, Forces by Earthquakes to Structures Not Vulnerable to Vibrations.
Current: 1961
Developing: no

Horizontal Regularity:
2.1 Building Shape
In all seismic areas of zones 1 to 4, the following regulations shall apply:
-The floor plan of the building should be as compact as possible. Buildings with complicated plans or with varying heights should be divided into box-like construction parts by separations.

2.2 Reinforcement
Load carrying elements should be regularly and symmetrically distributed over the plan. The centre of gravity of these elements should locate as close to the centre of masses as possible in order to minimise torsional oscillations.

Vertical Irregularity:
2.1 Building Shape
In all seismic areas of zones 1 to 4, the following regulations shall apply:
-Massive construction elements supported on slender structural units must be avoided, eg tall buildings supported on large span construction.

2.2 Reinforcement
It must be avoided:
-Walls which do not continue through all stories or walls with large openings, both causing a highly non-uniform variation in stiffness along the height.
-Different floor levels (i.e. staggered floors).

Analysis:
1. Scope
Buildings not vulnerable to vibrations are ordinary apartments, office and industrial buildings which are reinforced in every story and which have no larger floor spans in upper storeys than in lower storeys.

4. Earthquake Forces
Generally, for buildings not vulnerable to vibration, this standard considers only the horizontal component of the equivalent static force acting at each floor level in the most unfavourable direction for the structure.

Bulgaria

Year: 1987
Title: Bulgarian Code for Design of Buildings and Structures in Seismic Regions
Current: 1987
Developing: no

Horizontal Regularity:
Article 3
(1) The design of Buildings and structures in seismic regions shall comply with the following general requirements:
2. Mainly symmetrical building configurations with mass and stiffness uniformly distributed in plan and in height shall be selected.
3. Buildings with complex irregular shape or with significant dimensions in plan as well as buildings with different structural systems and different storey numbers shall be separated by means of seismic joints in accordance with Article 25.

Article 25
(1) Buildings and structures shall be separated by seismic joints when:
1. The building has an irregular shape in plan

Vertical Regularity:
Article 3
(1) Design of Buildings in seismic regions shall:
2. Mainly symmetrical building configurations with mass and stiffness uniformly distributed in plan and in height shall be selected.
3. Buildings with complex irregular shape or with significant dimensions in plan as well as buildings with different structural systems and different storey numbers shall be separated by means of seismic joints in accordance with Article 25.

Article 25
(1) Buildings and structures shall be separated by seismic joints when:
2. Frame structures with a difference in floor levels of adjacent sections.
3. The difference in height of the adjacent sections of the buildings is 6m or more.

Analysis:
Article 5
(2) Seismic excitations can have any direction in space. For rectangular shaped buildings and structures it can be assumed that the seismic loads are applied separately along their longitudinal and transverse axes. For buildings and structures of complex geometric shape the most dangerous direction of the seismic excitation shall be considered, and the spatial vibration of the structure, including torsion shall be studied.

Canada

Year: 1990
Title: National Building Code of Canada
Current: 1995
Developing: no

Horizontal Regularity:
4.1.9.1 Analysis
24) Where the centroids of mass and the centres of stiffness on the different floors do not lie approximately on vertical lines, a dynamic analysis should be carried to determine the torsional effects.

Vertical Regularity:
4.1.9.3 Special Provisions
5) For buildings in velocity or acceleration related seismic zones of 2 and higher in which discontinuities in columns or shear walls occur, special design provisions shall be made to ensure that failure at the point of discontinuity will not occur before the capacity of the remaining structure has been realised.

4.1.9.1 Analysis
21) Where a vertical resisting element is discontinuous, the overturning moment carried by the lowest story of that element shall be carried down as loads to the foundation.
25) The building design shall take full account of the possible effect of setbacks.

Analysis:
4.1.9.1 Analysis
24) Where the centroids of mass and the centres of stiffness on the different floors do not lie approximately on vertical lines, a dynamic analysis should be carried to determine the torsional effects.

Chile

Year: 1996
Title: Earthquake Resistance Design of Buildings.
Current: 1996
Developing: yes

Horizontal Regularity:
5.5.2.2
When buildings with irregular plans (in H, L, T, U etc) are designed as one structure, diaphragms shall be designed and constructed so that the construction will behave as an integral unit during earthquakes, and the provision 5.5.2.1 taken into account. Otherwise, each part will have to be designed as a separate structure in conformance with the provisions of paragraph 5.10.

5.5.2.3
If the building of irregular plan is designed as one structure, special attention shall be given to the design of the connections between its different parts.

Vertical Regularity:
5.5.2.4
At levels where there is a stiffness discontinuity in the resisting planes or other vertical substructure, it may be verified that the diaphragm will be capable of redistributing the forces.

Analysis:
5.6
The static analysis method may be used if the limitations set forth in paragraph 6.2.1 are satisfied. The limitations for use of the spectral modal analysis method are specified in paragraph 6.3.1.

6.2.1
The method of static analysis can only be used in the seismic analysis of the following resisting structures:
a) all the structures of category C and D located in seismic zone I
b) all the structures that do not exceed more than 5 stories nor 20 m in height.
c) 6 to 15 storey structures, provided that they comply with the following conditions for each direction of analysis.
  i) The quotients between the total building height H, and the modal periods with the highest translational equivalent mass in X and Y directions Tx and Ty respectively, must be equal to or more than 40 m/s.
  ii) the distribution of the horizontal seismic forces of the static method must be such that shears and overturning movements at each level, shall not differ in more than 10% with respect to those obtained through a spectral modal analysis with the same base shear.

6.3.1
This method can be applied to structures that have classical normal modes of vibration, with modal damping of about 5% of the critical damping.

China, People's Republic of

Year: 1989
Title: GBJ 11-89 National Standard of People's Republic of China; Aseismic Building Design Code.
Current: 1989
Developing: yes

Horizontal Regularity:
2.2 Arrangement of Plan and Elevation
Article 2.2.1
The plan and elevation arrangements of buildings should be regular and symmetrical, their weight and stiffness should be uniformly distributed and their floor levels should not be staggered.

Article 2.2.2
Aseismic joints can be installed according to practical necessities. For the building of a complicated configuration and with no use of seismic joints, the model for structural analysis should account sufficiently for its actual performance.
When using aseismic joints, the building should be separated into separate regular units. Beside the joints, structural units should be completely isolated.

Vertical Regularity:
2.2 Arrangement of Plan and Elevation
Article 2.2.1
The plan and elevation arrangements of buildings should be regular and symmetrical, their weight and stiffness should be uniformly distributed and their floor levels should not be staggered.

Analysis:
4.1 General Provisions
Article 4.1.2
The following methods shall be taken for seismic computations of any type of building structure:
1. For structures, not higher than 40 m, with deformations predominantly due to shear and a rather uniform distribution of mass and stiffness in elevation, or for structures modelled as a single-mass system, a simplified method, such as the base shear method, may be used.
2. For building structures other than those stated in the above clause, the response spectrum method for modal analysis should be used.
3 For buildings with extremely irregular configuration, buildings of type A, and high rise buildings within the height range given in Table 4.1.2, a time-history analysis procedure should be used as an additional safeguard.

Columbia

Year: 1998
Title: NSR-98 Standard Requirements for Buildings
Current: 1998
Developing: yes

Horizontal Regularity:
Table A.3-6 Irregularities in Plan
1P Torsional Irregularity
The torsion irregularity exists when the maximum story drift of the structure edge, calculated including the accidental torsion and measured perpendicularly to a determined axis, is more than 1.2 times the average drift of the two structure edges, with respect to the same reference axis.
2P Excessive Retrocession in the Corner
The structure configuration shall be considered irregular when this has excessive retrocession in their corners. A retrocession in a corner shall be considered excessive when the structure projections, in both sides of the retrocession, are greater than 15 % of the structure plant dimension in the retrocession direction.
3P Discontinuities in the Diaphragm
When the diaphragm has an appreciable discontinuities or variation in its rigidity, including the discontinuities caused by opening, entrance, retrocession or hollow with greater area than 50 % of the net diaphragm area or exit change of the diaphragm effective rigidity greater than the 50% among consecutive levels, the structure shall be considered irregular.
4P Action Plane Displacement of Vertical Elements
The structure shall be considered irregular when exists discontinuities in the force trajectory induced by seismic effects, as such is moved the plane that contains a vertical elements group of the seismic resisting system, in their perpendicular direction, generating a new plane. The attic of only one story shall be exempt of this requirement in irregularity consideration.
When exists discontinuities in the force trajectory induced by seismic effects, as such is moved the action plane of vertical elements of the seismic resistant system, the structure shall be considered irregular.
5P No Parallel System
When the direction of vertical element horizontal action of the seismic resistant system is not parallel or symmetric in relation to the principal horizontal orthogonal axis of the seismic resistant system, the structure shall be considered irregular.

Vertical Regularity:
Table A.3-7 Irregular in Height
1P Flexible Story (Irregularity in Rigidity)
When the rigidity in front of horizontal forces of a story is lesser than 70 % of the superior story rigidity or lesser than 80% of the average of three superior stories rigidity, the structure shall be considered irregular.
2P Irregularity in the Mass Distribution:

When the mass, m of any story is greater than 1.5 times the mass of either continuous story, the structure shall be considered irregular. Except for roof cases when this is lighter than the story below.

3P Geometrical Irregularity

When the horizontal dimension of the seismic resistant system in any story is greater than 1.3 times the same dimension in an adjacent story, the structure shall be considered irregular. Except for the attic case of only one story.

3P Displacement Inside of the Action Plane

The structure shall be considered irregular when exists displacements in the vertical elements alignment of the seismic resistant system, inside of the own plane where is containing, and these displacements are greater than the horizontal element dimension. When the elements are displaced that only support the building roof without other additional loads as equipment or tanks, are expected of this irregularity consideration.

4P Displacement inside of the Action Plane

When exists vertical element displacement of the seismic resistant system, inside of the action plane, greater than the horizontal dimension of the element, the structure shall be considered irregular.

5P Soft Story -Discontinuity in the Resistance

When the story resistance is lesser than 70% of the immediately upper story, inside of the action plane, greater than the horizontal dimension of the element, the structure shall be considered irregular.

Analysis:

A 1.3.4 Step 6

Irregularity grade of Structure and Analysis procedure:

Seismic analysis procedure of the structure according to the regularity or irregularity of the building configuration in plan as well as its elevation height, soil characteristics in site and in the seismic risk level shall be presented in Chap A3 of this regulation.

A.3.4.2 Analysis Method to Be Used

A.3.4.2.1 Equivalent Horizontal Force Method - can be used in the following buildings:

a) All the regular and irregular buildings in low seismic risk zones

b) All regular and irregular buildings belonging to the group of use I which are located in moderate seismic risk zone,

c) Regular buildings less than 20stories or 60 m in height measured from the base, which are located in any seismic risk zone, except for buildings located in the places with soil profile of type S4 and with the vibration periods longer than 0.7 seconds,

d) Irregular buildings less than 6 stories or 18 m in height

e) Flexible structures supported on much more rigid structures, which satisfies the requirements in A.3.2.4.3

A.3.4.2.2 Elastic Dynamic Analysis Method - can be used in each of the buildings

which are not covered by A.3.4.2.1 including the following:
a) Buildings with more than 20 stories or 60 m in height, except for the buildings mentioned in A.3.4.2.1 a) and b),
b) Buildings with vertical irregularities of types 1A, 2A and 3A, as being defined in A.3.3.5,
c) Buildings with vertical, which are not described in 1A. 2A and 3A except for the case described in A3.4.2.3.
d) Buildings with more than 5 stories or 20 m in height which are located in high seismic risk zone and do not have the same structural system along through the height of the same buildings having the exceptions mentioned in A.3.2.4.1 and
e) Regular or irregular structures which are located in places with soil profile of type S4 and vibration periods longer than 0.7 seconds. In this case, the analysis shall include the soil-structure interaction effects such as being prescribed in Chap A.7

Figures:

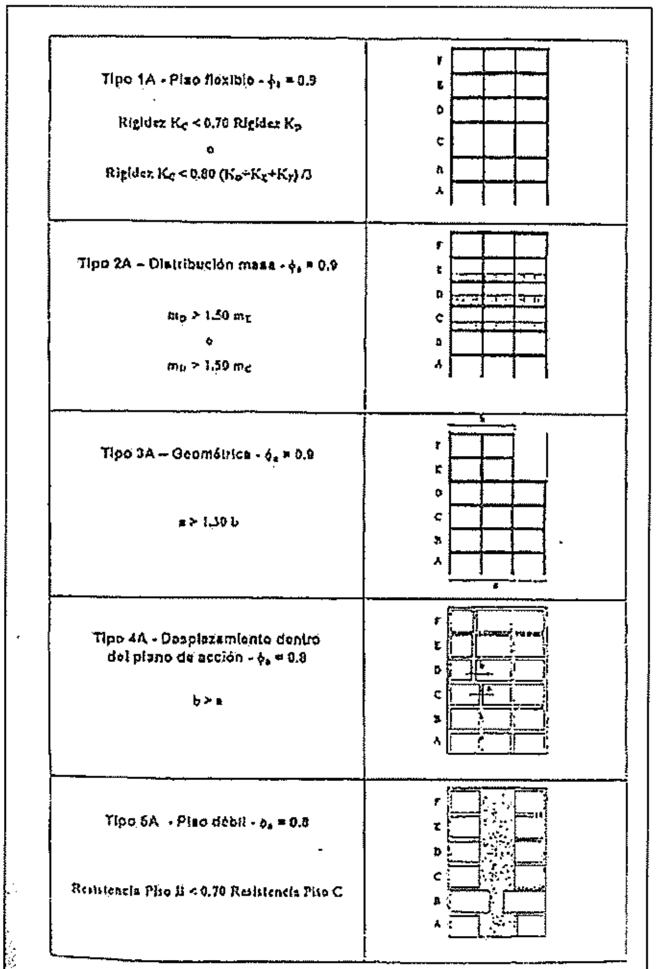


Figure A.3-2 Irregularities in height

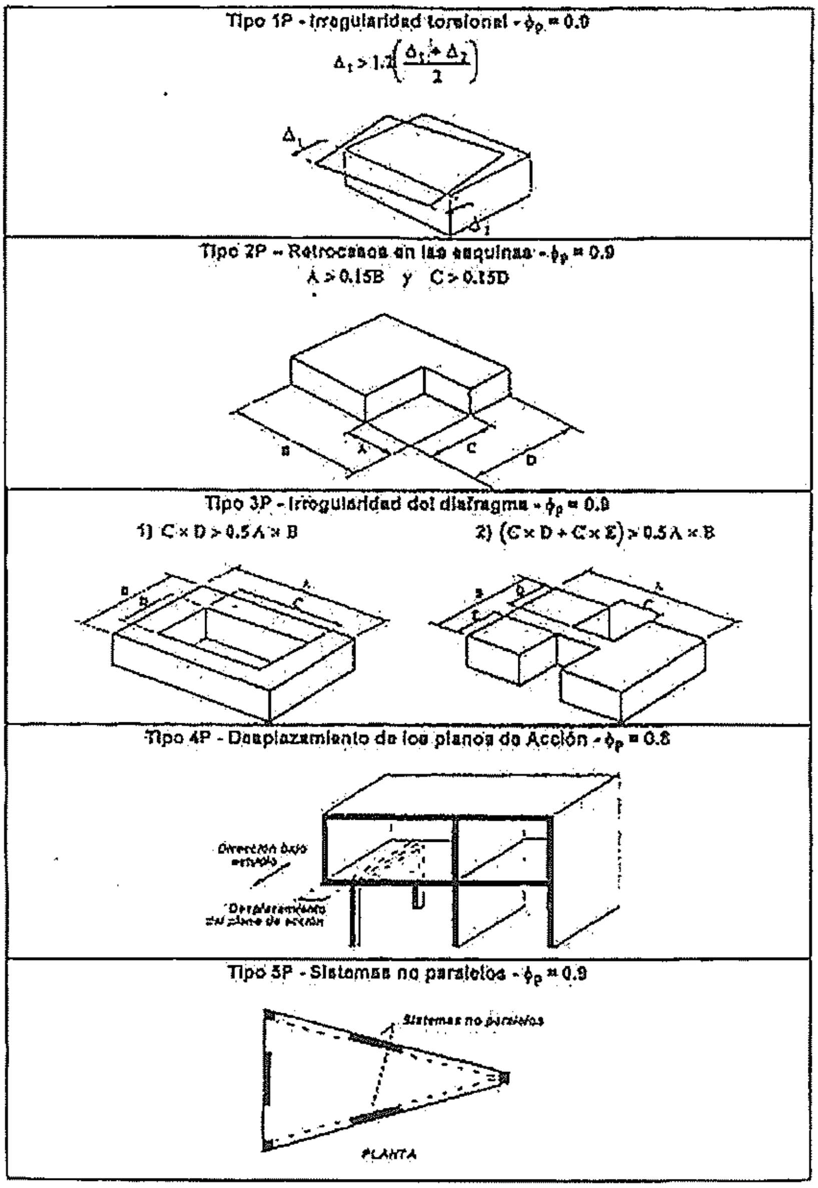
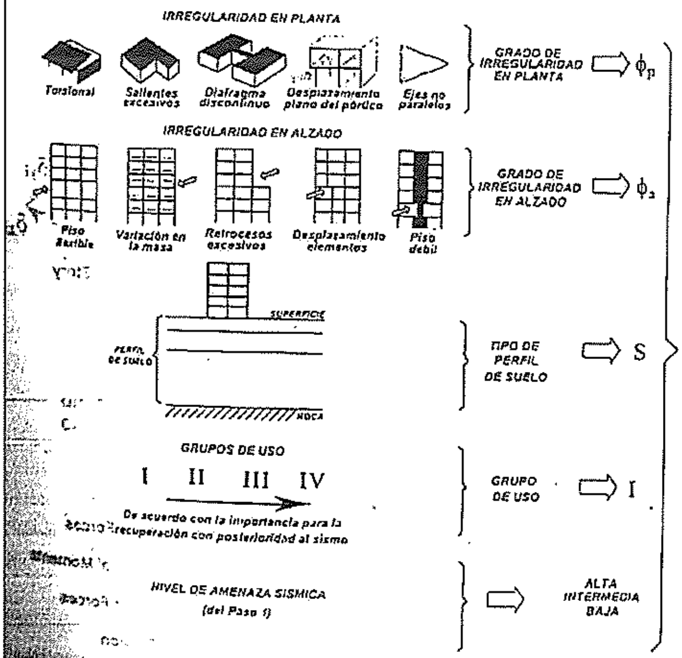


Figure A.3-1 Irregularities in plan

Step 4 – Grade of Irregularity of structure and analysis procedure



DEFINITION OF ANALYSIS PROCEDURE

Equivalent Horizontal Force Method

Elastic Dynamic Analysis Method

Inelastic Dynamic Analysis Method

Figure 9 – Procedure for defining grade of irregularity of structure and seismic analysis methods

Costa Rica

Year: 1986
Title: Seismic Code of Costa Rica
Current: 1986
Developing: yes

Horizontal Regularity:
2.3.6
Definition of a building as regular in plan upon satisfaction of the following requirement:
-eccentricity in each direction of X and Y does not exceed at every level i, more than 5% of the dimension of plan in that direction.

2.3.7
Buildings with eccentricities larger than 30% of the plan dimension in any of their principal directions are not approved.

Vertical Regularity:
2.3.5
A building with multiple floors is judged to be regular when the following requirements are met:
a) All resisting systems are continuous from foundations to top level
b) Weight of floors does not vary beyond 15% of the weight of adjacent floors. Roof or top level whose weight is less than the weight of adjacent floor, and any floor located at a height lower than 20% of the building height are exempt
c) In each resisting system, the stiffness of horizontal translation attributed to each floor shall be between 50-100% of the stiffness of adjacent lower floor.
d) Floor heights cannot differ over 20% with the heights of adjacent floors, except the first floor.
e) The projection of mass centres of all levels onto the horizontal plane shall fall within a rectangle, each dimension of which is equal to 10% of the max dimension in its orthogonal direction. (Also for stiffness centres)

Analysis:
2.1.2
Regardless of the sophistication levels in analysis and design, or of the quality of construction, buildings shall be planned under the symmetry conditions of structure and under a careful choice of construction materials and methods.

2.6.2
In view of the approximate character of this method, its use is limited to structures satisfying the following three conditions:
a) Buildings regular in elevation according to article 2.3.5
b) Buildings regular in plan according to article 2.3.6, except for the particular cases indicated in the article 2.6.10

c) Buildings whose number of floors is not more than seven, or whose total height from the street or access level does not exceed thirty meters.

Cuba

Year: 1964
Title: Standards for Structural Design: Seismic Loads
Current: 1964
Developing: yes

Horizontal Regularity:
214.2 Selection of Method for Determining Seismic Forces
Simplified method for determining seismic forces may be accepted if the following requirement are met at the same time:
b) there must be at least two perimeter bearing walls either parallel or forming an angle not greater than 20% connected by the floor slabs for a length equal to at least 50% of the dimension of these walls.

Vertical Regularity:
214.2 Selection of Method for Determining Seismic Forces
Simplified method for determining seismic forces may be accepted if the following requirement are met at the same time:
a) on each storey at least 75% of the vertical load is supported by walls tied together by continuous slabs.
c) the ratio of height to minimum dimension at base of the building must not exceed 1.5
d) the ratio of length to width of the building must not exceed 2.0 unless for purposes of seismic analysis where each storey may be considered divisible into independent sections whose length -width ratio satisfies this requirement.

Analysis:
214.2 Selection of Method for Determining Seismic Forces
Simplified method for determining seismic forces may be accepted if the following requirement are met at the same time:
a) On each storey at least 75% of the vertical load is supported by walls tied together by continuous slabs.
b) There must be at least two perimeter bearing walls either parallel or forming an angle not greater than 20% connected by the floor slabs for a length equal to at least 50% of the dimension of these walls.
c) The ratio of height to minimum dimension at base of the building must not exceed 1.5
d) the ratio of length to width of the building must not exceed 2.0 unless for purposes of seismic analysis where each storey may be considered divisible into independent sections whose length -width ratio satisfies this requirement.

Egypt

Year: 1988
Title: Regulations for Earthquake
Current: 1988
Developing: yes

Horizontal Regularity:
2.1 Symmetry
2.1.1
The main element of a building that resists seismic forces shall, as nearly as is practicable be located symmetrically about the centre of mass of the building.

2.3.4.2
The distribution of horizontal seismic forces in major buildings that have highly irregular shapes, large differences in lateral resistance or stiffness between stories, or other unusual structural features shall be determined in accordance with the dynamic analysis procedure of 2.4.

Vertical Regularity:
2.3.4.2
The distribution of horizontal seismic forces in major buildings that have highly irregular shapes, large differences in lateral resistance or stiffness between stories, or other unusual structural features shall be determined in accordance with the dynamic analysis procedure.

2.3.7.1
For buildings with setbacks where the plan dimension of the tower portion in each direction is at least 75% of the corresponding plan dimension of the lower part, the effect of the setback may be neglected.

2.3.5.3
For irregular structures more than five stories high, horizontal torsional effects shall be taken into account by the three-dimensional modal analysis of clause 2.4.2.2.2

Analysis:
2.2 Methods of Analysis
2.2.1
Buildings shall be analysed by the equivalent static force method specified in section 2.3. In addition a dynamic analysis as specified in section 2.4 shall be approved for any building and may be required by the engineer for any building where, in his opinion, special circumstances exist, for example where a building is of particular importance to the community, or where a special study is required by these regulations.

2.3.4.2

The distribution of horizontal seismic forces in major buildings that have highly irregular shapes, large differences in lateral resistance or stiffness between stories, or other unusual structural features shall be determined in accordance with the dynamic analysis procedure.

Ethiopia

Year: 1983
Title: Code of Practice for Loadings, Ethiopia
Current: 1983
Developing: yes

Horizontal Regularity:
7.4.3 Irregular Structures or Framing
The distribution of lateral forces in structures which have highly irregular shapes, large differences in lateral resistance or stiffness between adjacent stories or other unusual structural features shall be determined according to specialist literature considering the dynamic characteristics of the structure.

Vertical Regularity:
7.4.3 Irregular Structures or Framing
The distribution of lateral forces in structures which have highly irregular shapes, large differences in lateral resistance or stiffness between adjacent stories or other unusual structural features shall be determined according to specialist literature considering the dynamic characteristics of the structure.

7.4.2 Setbacks
Buildings having setbacks wherein the plan dimension of the tower in each direction is at least 75% of the corresponding plan dimension of the lower part may be considered as uniform buildings without setback.

Analysis:
7.8 Alternate Determination and Distribution of Seismic Forces
Nothing in this code shall be deemed to prohibit the submission of properly substantiated technical data for establishing the lateral forces and distribution by dynamic analysis. In such analysis the dynamic characteristics of the structure shall be considered.

(Europe)
Year: 1994
Title: Eurocode 8 Design Provision for Earthquake Resistance of Structures
ENV 1998-1-1:1994
General Rules: Seismic Actions and General Requirements for Structure
ENV 1998-12:1994 General Rules: General Rules for Buildings
Current: 1994
Developing: no

Horizontal Regularity:
2.2.4.1 Design
1) Structures should have simple and regular forms both in plan and elevation. If necessary this may be realised by subdividing the structure by joints into dynamically independent units.

Vertical Regularity:
2.2.4.1 Design
1) Structures should have simple and regular forms both in plan and elevation. If necessary this may be realised by subdividing the structure by joints into dynamically independent units.

c) In case the setbacks do not preserve symmetry, in each face the sum of the setbacks at all storeys is not greater than 30% of the plan dimension at the storey, and the individual setbacks are not greater than 10% of the previous plan dimension.

Analysis:
2.2 Structural Regularity
2.2.1 General
1) For the purpose of seismic design, building structures are distinguished as regular and non-regular.
2) This distinction has implications on the following aspects of seismic design:
- the value of the behaviour factor q, which can decrease depending on the type of non-regularity in elevation, i.e.:
    - geometric non-regularity exceeding the limits given in 2.2.3.(4)
    - non-regularity distribution of over strength in elevation exceeding the limits given in 2.2.3.(3).

3) With regard to the implications of structural regularity on the design, separate consideration is given to the regularity characteristics of the building in plan and in elevation, according to table 2.1.
4) Criteria describing regularity in plan and elevation are given in 2.2.2 and 2.2.3, rules concerning modelling and analysis are given in 3; the relevant behaviour factors are given in Part 1-3.

Figures:

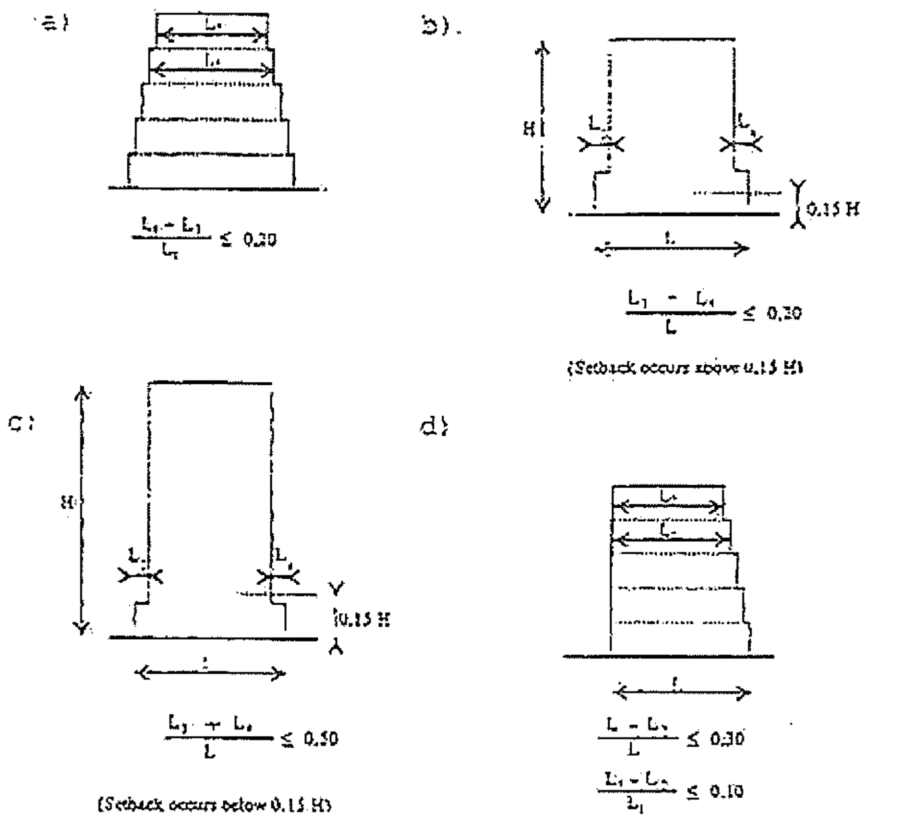


Figure 2.1: Criteria for regularity of setbacks

France

Year: 1990
Title: AFPS 90 Recommendations for the Reduction of Rules Relative to the Structures and Installations Built in Regions Prone to Earthquakes.
Current: 1990
Developing: no

Horizontal Regularity:
6.621.2 Regularity conditions
d) the plane construction shape, as well as the distribution of masses and stiffnesses along the height, must verify the regularity conditions indicated in part V.

Vertical Regularity:
6.621.1 Construction course
a) The structure may not include any vertical bearing element whose load is not transmitted along a direct line to the foundation.

6.621.2 Regularity conditions
d) the plane construction shape, as well as the distribution of masses and stiffnesses along the height, must verify the regularity conditions indicated in part V.

Analysis:
6.62 Simplified Methods
Ordinary type structures may, subject to the conditions specified in the present document, be calculated using the simplified methods described hereafter.

6.623.2 Period
In the case of regular structures, the fundamental mode may be estimated using experiment based formulas. In other cases, it will be calculated according to the usual dynamics method.

Germany

Year: 1981
Title: German Standard DIN 4149 Part 1
Buildings in German Earthquake Zones; Design Loads, Dimensioning, Design and Construction of Conventional Buildings
Current: 1981
Developing: no

Horizontal Regularity:
5.1 Shape of Structure
The ground-plan of the buildings shall be as compact as possible. Buildings with a ground-plan in order or angled shaped, or with a staggered arrangement of the storeys must be subdivided into square shaped structural bodies as far as possible by means of expansion joints. Structural bodies with large and heavy solidiums resting on slender constructional members must be avoided (e.g. High buildings with lower floors in open order).

5.2 Stiffening
Stiffening elements shall be of approximately equal stiffness and shall be distributed uniformly and as symmetrically as possible over the ground-plan. The centre of gravity of the rigidities of the stiffening elements and the mass centre of gravity shall be situated very close to one another, in order to avoid any undue torsional vibrations.

Vertical Regularity:
5.2 Stiffening
The following must be avoided:
a) Walls which do not pass uninterruptedly through all the stories, or walls with large cut-outs, which result in great differences in the uniformity of the rigidity over the height.
c) Differing floor elevations (staggered).

Analysis:
8.1 General Method of Determining the Earthquake Loads
For the purpose of calculating the earthquake loads, the masses of individual structure sections may be amalgamated into mass points. The dynamic action of the earthquake is calculated with the following static substitute loads, acting horizontally and applied at the respective mass points, for the natural vibration forms of the structure which have to be considered.

Greece

Year: 1984
Title: Anti-seismic Regulations for Building Construction
Current: 1995
Developing: no

Horizontal Regularity:
Article 6
2). In cases of usual constructions for the analysis of a supporting organisations with partitions of L, T, I etc sections, it is permitted that these sections are substituted by rectangular ones.
5). For elongated buildings, as well as for structure with sections of different height or of different number of floors between them with a skeleton of reinforced concrete, the strength of the plate at the differential points of the sectional plan and especially of the weakest should be considered.

Article 5
3). In order to obtain a more economical construction and a clearer provision of its seismic response, it is advisable to arrange as symmetrically as possible the vertically supporting elements on ground-plan in two shafts of these elements to be arranged into parallel rows to the centre of symmetry.

Vertical Regularity:
Article 5
4). The arrangement of the partitions of rigidity into proper and lying above one floor each from the other places, and which they and, if possible, at their limits into supports or transversally crossed partitions is suggested.
5). It is also advisable that the construction should present correspondence of the vertically being elements as far as the height is concerned.

Article 6
5). For elongated buildings, as well as for structure with sections of different height or of different number of floors between them with a skeleton of reinforced concrete, the strength of the plate at the differential points of the sectional plan and especially of the weakest should be considered.

Analysis:
Article 4
1). For the control of the seismic strain of the building, seismic forces will be inserted in the calculation, besides the calculated loads by the familiar regulations. It is allowable only the horizontal components of seismic forces to be inserted in calculation taken with alternated trend. In special circumstances as it is defined later, the vertical components of seismic forces will also be taken obligatorily into consideration.

India

Year: 1984
Title: Indian Standard. Criteria for Earthquake Resistant Design of Structures
Current: 1984
Developing: yes

Horizontal Regularity:
4.2.1
The criteria for design of multi-storeyed buildings shall be as follows:
d) NOTE 1
For buildings having irregular shape and/or irregular distribution of mass and stiffness in horizontal and/or vertical plane it is desirable to carry out modal analysis using response spectrum method

Vertical Regularity:
4.2.1
The criteria for design of multi-storeyed buildings shall be as follows:
d) NOTE 1
For buildings having irregular shape and/or irregular distribution of mass and stiffness in horizontal and/or vertical plane it is desirable to carry out modal analysis using response spectrum method

Analysis:
4.2.1
The criteria for design of multi-storeyed buildings shall be as follows:
c) The following methods are recommended for various categories of buildings in various zones:

Height:	Zone:	Recommended Method:
>40m	III, IV, and V	Detailed dynamic method
>90m	I and II	Modal analysis (response spectrum)
40>x>90m	All zones	Modal response
<40m	All zones	Modal Analysis

d) NOTE 1
For buildings having irregular shape and/or irregular distribution of mass and stiffness in horizontal and/or vertical plane it is desirable to carry out modal analysis using response spectrum method.

Figures:

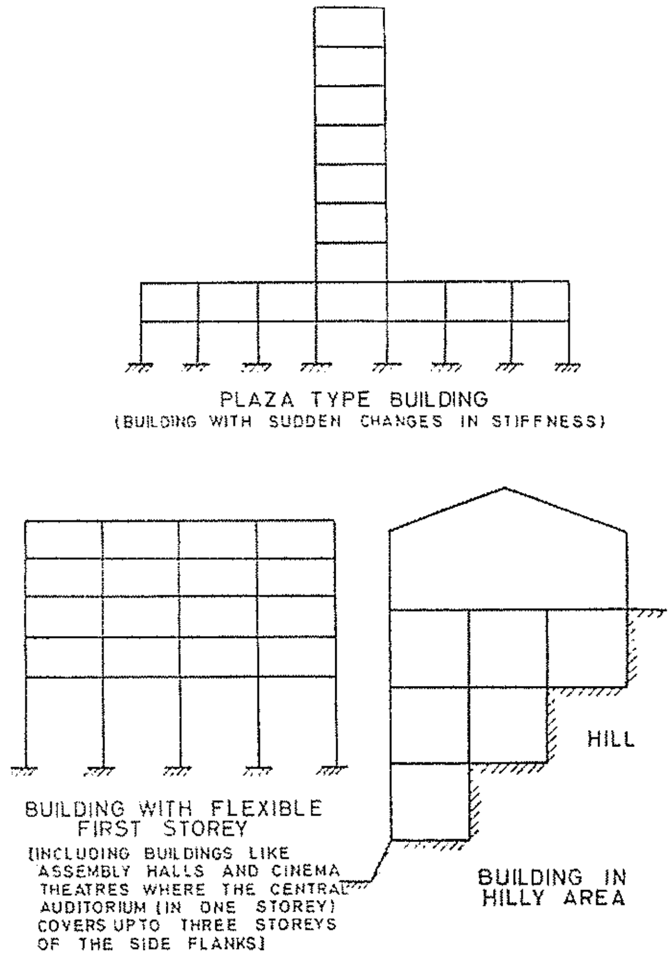


FIG. 4 BUILDINGS IN WHICH CLAUSE 4.2.1.1 SHALL NOT BE APPLICABLE

Indonesia

Year: 1983
Title: Indonesian Earthquake Code
Current:
Developing: yes

Horizontal Regularity:
3.2.3 Symmetry
The seismic load resisting elements of a structure should be located as nearly as practicable, symmetrically about the centre of mass of the structure.
Re-entrant angles in plan shape of a structure should be avoided. Where this is not feasible and the length of the wings exceeded 1/4 the width of the core section of the structure, the structure shall be treated as highly irregular. Highly irregular structures shall be designed using a 3D modal analysis as defined in clause 3.5.2.4 to determine the torsional response.

Vertical Regularity:
3.2.4 Setbacks
For buildings with setbacks where the plan dimension of the tower in each direction is at least 75% of the largest corresponding plan dimension of the lower part the earthquake design forces may be determined by the equivalent static load method in clause 3.4/
For buildings with setbacks which do not comply with this limit the distribution of horizontal seismic loads up the building shall be determined using a dynamic analysis as in clause 3.5. The equivalent static load method shall not be used.

3.2.5 Uniformity of storey stiffness
3.2.5.1
A dynamic analysis in accordance with clause 3.5 shall be used to determine the horizontal seismic load distribution for all structures in which the ratio of floor mass to the stiffness of the particular storey differs by more than 25% from the average for the structure.

Analysis:
3.2.4 Setbacks
For buildings with setbacks where the plan dimension of the tower in each direction is at least 75% of the largest corresponding plan dimension of the lower part the earthquake design forces may be determined by the equivalent static load method in clause 3.4
For buildings with setbacks which do not comply with this limit the distribution of horizontal seismic loads up the building shall be determined using a dynamic analysis as in clause 3.5. The equivalent static load method shall not be used.

Iran

Year: 1988
Title: Iranian Code for Seismic Resistant Design of Buildings
Current: 1988
Developing: yes

Horizontal Regularity:
1.4 Recommendations for Design
It is recommended to observe the following conditions in the design of buildings:
a) The plan of the building should be simple, symmetrical in both directions, without too many protrusions and recesses. Asymmetrical change of the plan in height of the building is to be avoided.
d) To reduce the torsional forces due to earthquake, the centre of mass of each storey and the centre of rigidity of that storey should coincide, or their distances in each one of the directions of the building should be less than 5% of the dimension of the building in that direction.

1.6.2 Characteristics of Regular Buildings
1.6.2.1 Regularity in Plan
a) The plan of the building has a generally symmetrical or approximately symmetrical configuration in the main axes of the building in which, usually the seismic resistance elements lie in these axes directions and, if there are recesses on that length does not exceed 25% of the outside dimension of the building in that direction.
b) In each storey, the distance between the centre of mass and the centre of rigidity in each of the two perpendicular directions of the building does not exceed 20% of the dimension of the building in that direction.

Vertical Regularity:
1.4 Recommendations for Design
It is recommended to observe the following conditions in the design of buildings:
a) Asymmetrical change of the plan in height of the building is to be avoided.
b) Elements supporting vertical loads on different storeys should be placed on one another so that the transmission of loads of these elements to one another will not take place through the horizontal elements.

1.6.2 Characteristics of Regular Buildings
1.6.2.2 Regularity in Elevation
a) When the distribution of the mass in the elevation of the building is approximately uniform so that the mass of none of the stories presents a variation of more than 50% in comparison with the mass immediately below or above it (with the exception of the attic).
b) Lateral rigidity in each storey, first, is not reduced by more than 30% in relation to the lateral rigidity in the three stories below.

Analysis:

2.3.1 Design of Regular Buildings

Regular buildings can be designed by the equivalent static analysis method provided their height do not exceed 80 m. Regular buildings higher than 80 m shall be deigned by the pseudo-dynamic analysis method and/or the dynamic method.

2.3.2 Design of Irregular Buildings

Irregular buildings can be designed by the equivalent static method provided their height do not exceed 18 m and the number of storeys are not more than 5. This method is not adequate for the design of irregular buildings which have more than 18 m in height or more than 5 storeys. Such buildings, if they are regular in plan but irregular in elevation, shall be designed by either the pseudo-dynamic analysis method or the dynamic analysis method, and if they are irregular in plan (irrespective of whether or not they are regular elevation), they must be designed exclusively by the dynamic analysis method.

Israel

Year: 1995
Title: Design Provisions for Earthquake Resistance of Structures
SI 413 Israel Standard
Current: 1995
Developing: no

Horizontal Regularity:
203.1 Regular Structures
A structure that has all the following characteristics:
A. Horizontal Configuration:
-The structure has an approximate symmetrical layout. In the case of re-entrant features, the dimensions of each re-entrant shall not be greater than a quarter of the smallest external dimension of the structure (fig 1) if their depth is greater than the smaller between 2.5 m or 1/0 the horizontal dimension of the structure in the direction of the depth of re-entrant.
-The total floor area that serves as a diaphragm shall not be less than 1/2 the inner area of the discussed story.
-In every story, the distance d that is perpendicular to the direction of the seismic action (fig 4) between the mass and stiffness centres shall not exceed 15% of the rigidity radius calculated in this direction.
-There shall be no horizontal discontinuities in the lateral force resisting systems.
-The maximum calculated story drift, including the torsional effect, shall not be greater than 50% of the drift, at the opposite end of the same story.

203.2 Irregular Structures
A structure that violates any of the above conditions.

Vertical Regularity:
203.1 Regular Structures
A structure that has all the following characteristics:
<u>B. Vertical Configuration:</u>
-There is no restriction on the vertical configuration, in one story structure, or a two story structure with a height that is less than 11 m.
-There shall be no flexible story in the structure.
-There shall be no soft story in the structure.
-For framed structures, the ratio between story shear capacity and the design shear force shall not differ by more than 20% from story to story in all structures, or the two uppermost stories in structures with seven stories or more.
-There shall be no vertical discontinuity in the lateral force resisting system
-There shall be no story that its total mass is 50% larger than that of any story below.
-In a structure that its horizontal dimensions gradually decrease along the height of the structure (fig 2) there shall be no reduction in the dimension at the lower part of the structure (15% of the total height) and the dimension reduction in every floor above this part shall be less than 10% of the horizontal dimension in

the direction of the reduction.

203.2 Irregular Structures
A structure that violates any of the above conditions.

Analysis:
203 Structural Characteristics
Structures shall be designated as being regular or irregular.

203.3 Design Limitations
-The design of regular structures can be performed using the equivalent static analysis in all seismic zones, except in the case of structures that are taller than 80 m, r structures that their fundamental period is longer then 2 seconds.
-The design of the following structures shall be done only using the modal or the dynamic analysis, structures taller than 80 m, or structures that their fundamental period is longer than 2 seconds and irregular structures to which, according to table 9 the equivalent static method does not apply.
-A structure with an especially weak story that has a shear resistance to lateral force smaller than 0.65 times the shear resistance of the above story, can be constructed only if the following two conditions are fulfilled:
- the structure shall not have more than two stories
- the height of the structure from the base, shall be less than 9 m.

These two requirements shall not apply provided that the shear capacity of the weak story, the shear capacity of the story above, and the shear capacity of the story below are sufficient to carry a resultant lateral seismic load equals to 0.75K times the design load mentioned.

Japan

Year: 1992
Title: Standards for Aseismic Civil Engineering Constructions
Earthquake-Resistance Design Method for Buildings.
Current: 1992
Developing: no

Horizontal Regularity:

Vertical Regularity:
2.4
A Stiffness Eccentricity
The following stiffness eccentricity Re of each storey shall be less than 0.15.
Re = e/re where e= the eccentricity of the centre of stiffness from the centre of mass.
.
re= the elastic radius, which can be defined as the square root of the
torsional stiffness divided by the lateral stiffness.

Analysis:
1.2 Scope
Buildings exceeding 60 m in height will require special permission from the Minister of Construction following a detailed review of the dynamic behaviour of the structure by the board of technical members.

Korea

Year: 1988
Title: Building Code for Structural Regulations
Current: 1998
Developing: no

Horizontal Regularity:

5. Horizontal Torsional Moments

The Horizontal Torsional Moments shall be determined from the torsional moment resulting from the eccentricity between the centres of mass and stiffness plus an accidental torsional moment. In this case the accidental torsional moment shall be obtained by multiplying the lateral seismic force to the assumed accidental eccentricity corresponding to 5% of the plan dimension perpendicular to the direction of the load.

9. Irregular Structures

9.1 Irregular structures, featured by vertical irregularities and/or plan irregularities, have significant physical discontinuities in configuration or in their lateral-force-resisting systems.
9.3 Structures having any of the features listed in Table 8 shall be designed as having a plan irregularity.
9.4 Structures classified as Grade 2 in any seismic zone need to be evaluated only for vertical irregularities of type 5 and plan irregularities of type 1.

<u>Table 8 Plan Structural Irregularities</u>
1. Torsional Irregularity
Torsional Irregularity shall be considered to exist when the maximum story drift, computed including accidental torsion, at one end of the structure transverse to an axis is more than 1.2 times the average of the story drifts of the two ends of the structure.
2. Re-entrant Corners
Plan configurations of a structure and its lateral-force-resisting system contain re-entrant corners, where both projections of the structure beyond a re-entrant corner are greater than 15 % of the plan dimension of the structure beyond a re-entrant corner are greater than 15% of the plan dimension of the structure in the given direction.
3. Diaphragm Discontinuity
Diaphragms with abrupt discontinuities or variations in stiffness, including those having cut-out or open areas greater than 50% of the gross enclosed area of the diaphragm, or changes in effective diaphragm stiffness of more than 50% from one story to the next.
4. Out-of-Plane Offsets
Discontinuities in a lateral force path, such as out-of-plane offsets of the vertical elements.
5. Nonparallel systems

The vertical lateral-load-resisting elements are not parallel to or symmetric about the major orthogonal axes of the lateral-force-resisting system.

Vertical Regularities:

9. Irregular Structures

9.1 Irregular structures, featured by vertical irregularities and/or plan irregularities, have significant physical discontinuities in configuration or in their lateral-force-resisting systems.

9.2 Structures having any of the features listed in Table 7 shall be designed as having a vertical irregularity. Where no story drift under design lateral forces is greater than 1.3 times the story drift of the story above, the structure may be deemed not to have the structural irregularities of type 1 or 2 in table 7.

9.4 Structures classified as Grade 2 in any seismic zone need to be evaluated only for vertical irregularities of type 5 and plan irregularities of type 1.

Table 7 Vertical Structural Irregularities

1. Stiffness Irregularity

Stiffness irregularity shall be considered to exist where the lateral stiffness of a soft story is less than 70% of that in the story above or less than 80% of the average stiffness of the three stories above.

2. Weight Irregularity

Weight irregularity shall be considered to exist where the effective weight of any story is more than 150% of the effective weight of an adjacent story. A roof that is lighter than the floor below need not be considered.

3. Geometric Irregularity

Geometric irregularity shall be considered to exist where the horizontal dimension of the lateral-force-resisting system in any story is more than 130% of that in an adjacent story. Where the sum of projections of a penthouse is not greater than 1/8 times the plan area of the building structure, any penthouse not higher than 12 m need not be considered.

4. In-Plane Discontinuity in Lateral-force-resisting Elements

In-plane discontinuities shall be considered to exist where an in-plane offset of the lateral-load-resisting elements is greater than the length of those elements.

5. Discontinuity in Capacity

Discontinuity in capacity shall be considered to exist where the strength of a weak storey is less than 80% of that in the story above. The story strength is the total strength of all seismic-resisting elements sharing the story shear for the direction under consideration.

Analysis:

12. Dynamic Analysis Procedure

The dynamic analysis procedure shall be used for the structures of importance grade S or 1, which belong to one of the following conditions:

1) Regular structures with not less than either 70 m in height or 21 stories.

2) Irregular structures with not less than either 20 m in height or 6 stories

Mexico

Year: 1987
Title: Complementary Technical Norms for Earthquake Resistant Design
Current: 1995
Developing: yes

Horizontal Regularity:
6. Regularity Conditions:
Regular buildings must satisfy the following requirements:
1. The plan must be nearly symmetric with respect to two orthogonal axes. This condition applies to masses as well as all kinds of resisting elements.
4. The plan shall not have protruding or re-entrant portions with dimensions larger than 20% of the plan dimension measured parallel to the direction of the protruding portion or re-entrance considered.
6. Voids in roof or floor slabs shall have dimensions smaller than 20% of the plan dimension measured parallel to the dimension of the void considered. Voids must not introduce significant asymmetry and their position must not vary from floor to floor. The area of voids need not exceed 20% of the total area of the floor slab of interest.
11. At any story, the torsional eccentricity must not exceed 10% of the dimension in plan parallel to the eccentricity.

Vertical Regularity:
6. Regularity Conditions:
Regular buildings must satisfy the following requirements:
7. The mass of a given floor, including seismic live loads, shall not exceed the mass of the floor below it, and shall be less than 70% of this value. This restriction does not apply to the floor at the top.
10. The lateral shear stiffness of a given story must not exceed twice the value of the story below it.

Analysis:
2.1 Static and Dynamic Method
Every structure shall be analysed using the dynamic method as defined in section 9 of these provisions. Alternatively, structures under 60 m in height shall be designed using the static method of section 8. The same restriction is applicable to structures founded on seismic zones II and III according to the classification of article 219 of the code. Methods that take into accordance with the appendix of these norms can be used as well.

Nepal

Year: 1995
Title: Nepal National Building Code, Seismic Design of Buildings in Nepal NBC 105
Current: 1995
Developing: yes

Horizontal Regularity:
3.4 Symmetry
The seismic load resisting elements of a structure should be located, as nearly as practicable, symmetrically about the centre of mass of the structure. Re-entrant angles in the plan shape of a structure should be avoided.

Vertical Regularity:
3.5 Uniformity of Story Stiffness
Significant changes in the stiffness over the height of the building should be avoided.

5.2 Selection of Method of Analysis
For structures up to 40 m in height the seismic coefficient method may be used. For all other structures the modal response spectrum method shall be used. Modal spectrum method should be used for:
a) buildings with irregular configurations
b) buildings with abrupt changes in lateral resistance
c) buildings with abrupt changes in lateral stiffness with height
d) buildings with unusual shape, size, or importance.

New Zealand

Year: 1992
Title: Code of Practice for General Structural Design and Design Loadings for Buildings
NZS 4203:1992
Current: 1992
Developing: no

Horizontal Regularity:
4.4 Structural Regularity
4.4.1 Horizontal Regularity
For a structure to satisfy the horizontal regularity requirement for the use of the equivalent static or two-dimensional modal response spectrum and two-dimensional numerical integration time history methods of analysis the following criteria shall be satisfied:
(a) Either:
(i) The horizontal distance between the shear centre at any level and the centre of mass of all levels shall neither exceed 0.3 times the maximum plan dimension of the structure at that particular level, measured perpendicular to the direction of the applied lateral forces, nor change sign over the height of the structure.
or
(ii) Under the action of the equivalent static lateral forces as defined in 4.8.1 and 4.8.2, the ratio of the horizontal displacements at the ends of an axis transverse to the direction of the applied lateral forces shall be in the range 3/7 to 7/3.
and
(b) The diaphragms shall not contain abrupt variations in stiffness or major re-entrant corners such as could significantly influence the distribution of the lateral forces in the structure.

Vertical Regularity:
4.4 Structural Regularity
4.4.2 Vertical Regularity
To satisfy the vertical regularity requirements for the use of the equivalent static method, the lateral displacement of each level shall be reasonably proportional to its height above the base.

Analysis:
4.3.2 Limitations on the use of the Equivalent Static Method
The equivalent static method of analysis may be used provided one of the following criteria is satisfied:
a) The height between the base and the top of the structure does not exceed 15 m.
c) The structure satisfies the horizontal and vertical regularity requirements of Section 4.4 and has a fundamental period less than 2.0 seconds.

4.3.3 Use of three-dimensional Dynamic Analyses

A three-dimensional modal analysis or a three-dimensional numerical integration time history analysis shall be used for structures which do no comply with 4.3.2 and which do not satisfy the horizontal regularity requirements of 4.4.1.

Panama

Year: 1994
Title: Structural Design Regulations for the Republic of Panama REP-94
Current:
Developing: yes

Horizontal Regularity:
4.3.4 Building Configuration
The buildings shall be classed as regular or irregular in plan or in height according to the criteria of this section.

4.3.4.1 Irregularity in Plan
The building with one or more of the irregularity types given in Table 4.3.3 shall be classified as irregular in plan and shall satisfy the requirements of the remarked sections in the same table.

Table 4.3-3 Plan Structural Irregularities
1. Torsional Irregularity
The torsional irregularity shall be considered when the diaphragms are not flexible. The torsional irregularity shall be considered to exist when the maximum story drift, computed including accidental torsion, at one end of the structure transverse to an axis is more than 1.2 time the average of the story drifts of the two ends of the structure.
2. Re-entrant corners
Plan configuration of a structure and its lateral force-resisting system contain re-entrant corners, where both projections of the structure beyond a re-entrant corner are greater than 15% of the plan dimension in the given direction.
3. Diaphragm Discontinuity
Diaphragm with abrupt discontinuities or variations in stiffness, including those having cut-out or open area greater than 50% of the gross enclosed area of the diaphragm, or changes in effective diaphragm stiffness of more than 50% from one story to the next.
4. Out-of-plane offsets
Discontinuities in lateral force path, such as out-of-plane offsets of vertical elements that resist the seismic lateral forces.
5. Nonparallel Systems
The vertical lateral load-resisting elements are not parallel to or symmetric above the major orthogonal axes of lateral force-resisting system.

Vertical Regularity:
4.3.4 Building Configuration
The buildings shall be classed as regular or irregular in plan or in height according to the criteria of this section.

4.3.4.2 Irregularity in Height

The building with one or more of the irregularity types given in Table 4.3.4 shall be classified as irregular in plan and shall satisfy the requirements of the remarked sections in the same table.

Table 4.3-4 Vertical Structural Irregularities

1. Stiffness irregularity: a soft story

The soft story is one in which the lateral stiffness is less than 70% of that in the story above or less than 80% of the average stiffness of the three stories above.

2. Weight (mass) irregularity

Mass irregularity shall be considered to exist where the effective mass of any story is more than 150% of the effective mass of an adjacent story. A roof, which is lighter than the floor below, need not be considered.

3. Vertical Geometric Irregularity

Vertical geometric irregularity shall be considered to exist where the horizontal dimension of the lateral force-resisting system in any story is more than 130% of that in an adjacent story.

4.In-plane Discontinuity in Vertical Lateral Force-resisting Elements

An in-plane offset of the lateral load resisting elements greater than the length of those elements.

5.Discontintuity in Capacity: A Weak Story

A weak story is one where the story strength is lesser than 80% of that in the story above. The story strength is the total strength of all the seismic-resisting elements sharing the story shear for the direction under consideration.

Analysis:

4.3.5 Analysis Procedures

For all the buildings, their structural analysis shall be performed according to the requirements of this section. This section presents the minimum analysis procedure, which must be satisfied. An alternative procedure with general acceptance including the use of the specific response spectrum for a site can be permitted to use if the capable authority approves the adopted procedure.

4.3.6.4.2 Irregularity in Plan and Height

The design shall be consider the probability of adverse effects when the relation of resistance provided in any story is significantly less than the resistance of the above story. The resistance shall be adjusted to compensate this effect.
For buildings which have a irregularity in plan of types 1, 2, 3, or 4 in Table 4.3-3 or a structural irregularity in height of type 4 in Table 4.3-4, the design forces determined based on section 4.4 shall be increased 25% for the diaphragm connection to vertical elements and collectors, also for the connection of collectors to vertical elements.

Table 4.3-5 Analysis Procedure
(for seismic performance categories D and E)

1. Buildings designed as regular which does not exceed 72 m in height. (section 4.4)

2. Buildings with only vertical irregularities of type 1, 2, and 3 in Table 4.3-4 and have a height of more than 5 stories or 20 m, and all building with more than 72 m in height. (section 4.5)
3. The remaining buildings with vertical irregularities or irregularities in plan. (section 4.4)

Peru

Year: 1977
Title: Earthquake Resistant Standards, National Regulations of Construction
Current:
Developing: yes

Horizontal Regularity:
1.10 Structural Earthquake Resistance Conception
It has to be considered that the following conditions which improve the seismic behaviour of buildings.
a) Symmetry in mass and stiffness distribution.
d) Structural continuity as in plan as in elevation.

Vertical Regularity:
1.10 Structural Earthquake Resistance Conception
It has to be considered that the following conditions which improve the seismic behaviour of buildings.
a) Symmetry in mass and stiffness distribution
b) Least weight, especially in the upper most levels.
d) Structural continuity as in plan as in elevation

1.15.1 Reduction in Plan
If the reduced dimension in plan is not less than 3/4 parts of the dimension of the immediate lower story in the direction in which the earthquake is considered, the force H shall be calculate and shall be distribute in height according to the specification in 1.14. Similarly if the base of the building with reduction has the height less or equal to 30% of the total height of the building, it shall be considered that the reduction will not modify the distribution of H force.

Analysis:
1.17.1
a) For buildings more than 25 stories or higher than 75 m or for those cases when the general method is not accurate the dynamic analysis will be required.

Philippines

Year: 1992
Title: National Structural Code for Buildings
Current: 1992
Developing: yes

Horizontal Regularity:
3.2.3 Symmetry
The seismic load-resisting elements of a structure should be located as nearly as practicable, symmetrically about the centre of mass of the structure.
Re-entrant angles in the plan shape of a structure should be avoided. Where this is not feasible and the length of the wings exceeds one-quarter the width of the core section of the structure, the structure shall be treated as highly irregular.
Highly irregular structures shall be designed using a three dimensional modal analysis as defined in Clause 3.5.2.4 to determine the torsional response.

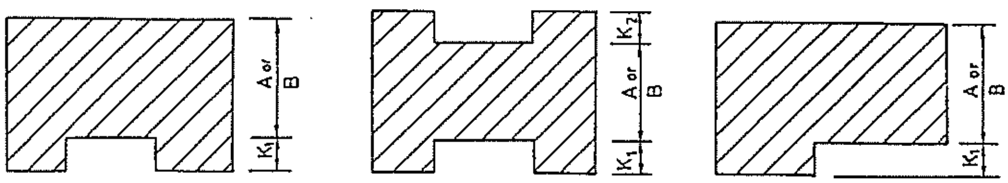
Vertical Regularity:
3.2.4 Set-backs
For buildings with set-backs where the plan dimension of the tower in each direction is at least 75% of the largest corresponding plan dimension of the lower part, the earthquake design forces may be determined by the equivalent static load method in clause 3.4.
For buildings with set-backs which do not comply with this limit, the distribution of horizontal seismic loads up the building shall be determined using a dynamic analysis as in clause 3.5. The equivalent static load method shall not be used.
A penthouse structure of not more than 2 storeys in height may not be considered as a setback.

3.2.5 Uniformity of Storey Stiffness
3.5.2.1
The ratio of floor mass to the stiffness of a particular storey shall not differ by more than 50% of the average for the structure. The storey stiffness is defined as the shear applied at the particular level which causes unit displacement of that level relative to the level below.
A dynamic analysis in accordance with clause 3.5 shall be used to determine the horizontal seismic load distribution for all structures in which the ratio of floor mass to the stiffness of any storey differs by more than 25% from the average for the structure.
Plant rooms, penthouses and the like at the top of a structure shall be exempt from this requirement if their floor area is less than 25% of a typical floor.

Analysis:
3.3 Method of Analysis
3.3.1 Selection of Method
For regular structures up to 40 m in height complying with the requirements of clause 3.2, the horizontal seismic loads may be determined by the equivalent

static load analysis specified in clause 3.4. For all other structures a dynamic analysis shall be carried out in accordance with clause 3.5.

Figures:



Treat as highly irregular if K_1, or $K_2 > 0.25A$ or $0.25B$

Fig. 3.1. IRREGULAR STRUCTURES

Portugal

Year: 1983
Title: Portuguese Seismic Code
Current: 1983
Developing: no

Horizontal Regularity:
30.4
The conditions that buildings shall comply with, are the following:
-Horizontal distribution of mass and stiffness should not be dissimilar.

Vertical Regularity:
30.4
The conditions that buildings shall comply with, are the following:
-Vertical distribution of mass and stiffness should not present sharp variations.

Analysis:
30.4
In case of buildings and bridges that satisfy the conditions presented below, the determination of the seismic action effects may be performed, in a simplified way, by supposing that static forces are applied to the structure, acting separately along the two perpendicular directions.

30.5
In case of buildings which do not satisfy the conditions set forth on 30.4, but have some ductility, a simplified method of static analysis may be resorted to.

Romania

Year: 1981
Title: Code for Aseismic Design of Residential, Public, Agricultural and Industrial Building
Current: 1992
Developing: yes

Horizontal Regularity:
2.2 Structural Shape
2.2.1
When selecting the shape and overall structural concept of the building, regular, compact and symmetrical forms shall be chosen, and strongly non-symmetrical distribution of volumes, masses and rigidities for the same building shall be avoided in order to control torsional effects.

Generally the construction of buildings with irregular or complicated layouts shall be avoided because of the potential occurrence of additional severe stresses at the discontinuities. In case these provisions cannot be implemented, the structure shall be separated by aseismic joints. Each portion of the building shall have an adequate shape and a proper distribution of volumes, masses and rigidities.

Vertical Regularity:
2.2 Structural Shape
2.2.2
Multi-storey buildings with setbacks shall have continuous vertical bearing elements, avoiding strong dissymmetry of the overall structure.

Analysis:
3.1.1
Seismic loads are determined based on the assumption that, for current design procedures and for linear analysis, inertial forces due to seismic oscillations of the structure may be represented by static, equivalent forces.

Switzerland

Year: 1989
Title: Swiss Standard SIA 160. Actions on Structures
Current: 1989
Developing: no

Horizontal Regularity:
Table 3. Measures for Buildings
Layout of the Structure
1. Adopt a symmetrical layout in plan for all structural elements transmitting horizontal forces, and design them to have similar deformation characteristics. Ensure interaction between these elements with adequate floor slabs and bracing systems, etc.
(Recommended for category I and II in medium and high seismic zones)
(exceptions must be justified for category III in all zones)

2. Diaphragms avoid deviations of more than 30% vertically, and from the mean values of stiffness or bending, shear and torsional resistance.
(Obligatory for category III, (highest) in medium and high seismic zones)

4.19.504
For buildings, the application of the equivalent force method is subject to the following conditions:
-the structure is less than 50 m
-the plan and layout of the structure and distribution of mass are approximately symmetric and without significant discontinuities throughout the height of the structure.

Vertical Regularity:
4.19.504
For buildings, the application of the equivalent force method is subject to the following conditions:
-The structure is less than 50 m.
-The plan and layout of the structure and distribution of mass are approximately symmetric and without significant discontinuities throughout the height of the structure.

Analysis:
4.19.504
For buildings, the application of the equivalent force method is subject to the following conditions:
-The structure is less than 50 m.
-The plan and layout of the structure and distribution of mass are approximately symmetric and without significant discontinuities throughout the height of the structure.

If the foregoing conditions are not satisfied, a more detailed method of calculation shall be used, such as the response spectrum method.

Turkey

Year: 1998
Title: Specifications for Structures to be Built in Disaster Areas (part III) Earthquake Disaster Prevention
Current: 1998
Developing: yes

Horizontal Regularity:
Table 6.1 Irregular Buildings
A. Irregularities in Plan:
A1: Torsional Irregularities:
The case where Torsional Irregularity Factor, which is defined for any two orthogonal earthquake directions as the ratio of the maximum storey drift at any story to the average story drift at the same storey in the same direction, is greater than 1.2 (fig 6.1). (6.3.2.1)
A2: Floor Discontinuities:
In any Floor (fig 6.2)
i) The case where the total area of the openings including those of stairs and elevator shaft exceeds 1/3 of the gross floor area.
ii) The case where local floor openings make it difficult the safe transfer of seismic loads to vertical structural elements.
iii) The case of abrupt reductions in the in-plane stiffness and strength of floors. (6.3.2.2.)
A3: Projections in Plan:
The case where projections beyond the re-entrant corners in both of the two principal directions in plan exceed the total plan dimensions of the building in the respective directions by more than 20%. (fig 6.3). (6.3.2.2)
A4: Nonparallel Axes of Structural Elements:
The cases where the principal axes of vertical structural elements in plan are not parallel to the orthogonal earthquake directions considered. (fig 6.4) (6.3.2.3)

Vertical Regularity:
Table 6.1 Irregular Buildings
B. Irregularities in Elevation:
B1: Inter-storey Strength Irregularity (Weak Storey):
In reinforced concrete buildings, the case where in each of the orthogonal earthquake directions, Strength Irregularity Factor, which is defined as the ratio of the effective shear area of any storey to the effective shear area of the storey immediately above, is less than 0.80. (6.3.2.4)
B2: Inter-storey Stiffness Irregularity (Soft Story)
The case where in each of the two orthogonal earthquake directions, Stiffness Irregularity Factor, which is defined as the ratio of the average storey drift at any storey to the average storey drift at the storey immediately above is greater than 1.5. (6.3.2.1)
B3: Discontinuity of Vertical Structural Elements:
The case where vertical structural element (columns or structural walls) are

removed at some stories and supported by beams or gusseted columns underneath, or the structural walls of upper stories are supported by columns or beams underneath (fig 6.6) (6.3.2.5)

Analysis:
6.3.1 Definition of Irregular Buildings
Regarding The definition of irregular buildings whose design and construction should be avoided because of their unfavourable seismic behaviour, types of irregularities in plan and in elevation are given in Table 6.1 and relevant conditions are given in 6.3.2.

6.3.2 Conditions for Irregular Buildings
6.3.2.1 Irregularity types A1 and B2 govern the selection of method of seismic analysis as specified in 6.6.
6.3.2.2 I buildings with irregularity types A2 and A3, it shall be verified by calculation in the first and second zones that the floor systems are capable of safe transfer of loads between vertical structural elements.
6.3.2.3 In buildings with irregularity type A4, internal forces along the principal axes of structural elements shall be determined in accordance with 6.7.5 and 6.8.6.

6.6.2 Applied Limits of Equivalent Seismic Load Method:
Buildings for which Equivalent Seismic Load Method given in 6.7 is applicable are summarised in Table 6.6. Methods given in 6.8 or 6.9 shall be used for the seismic analysis of buildings outside the scope of table 6.6.

Table 6.6

Zone	1, 2:	-buildings without type A1 torsional irregularities, or H< 25m
	1, 2:	-buildings without type A1 torsional irregularities and without type
-		B2 irregularities. H< 60m
	3, 4:	-all buildings.

Figures:

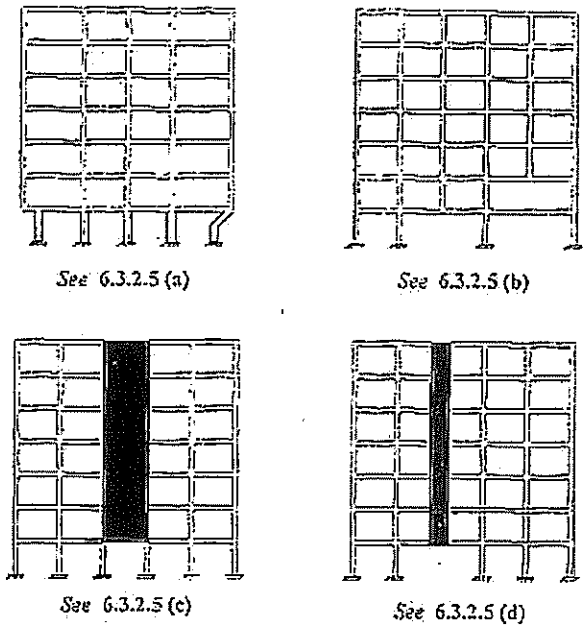
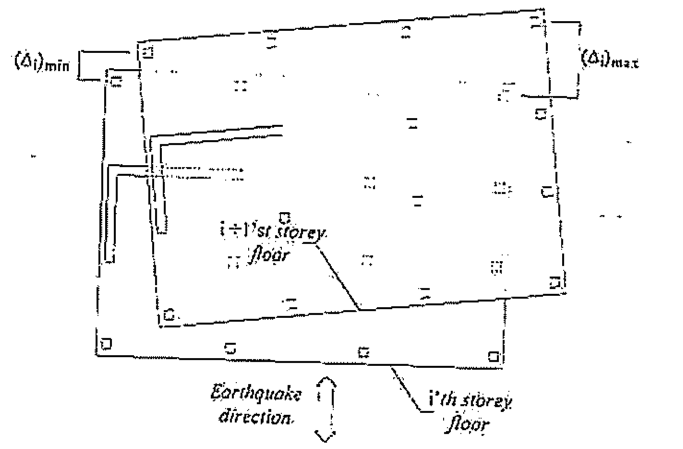


Figure 6.5



In the case where floors behave as rigid diaphragms in their own planes:

$$(\Delta_i)_{ort} = 1/2\,[(\Delta_i)_{max} + (\Delta_i)_{min}]$$

Torsional irregularity factor:

$$\eta_{bi} = (\Delta_i)_{max} / (\Delta_i)_{ort}$$

Torsional irregularity: $\eta_{bi} > 1.2$

Figure 6.1

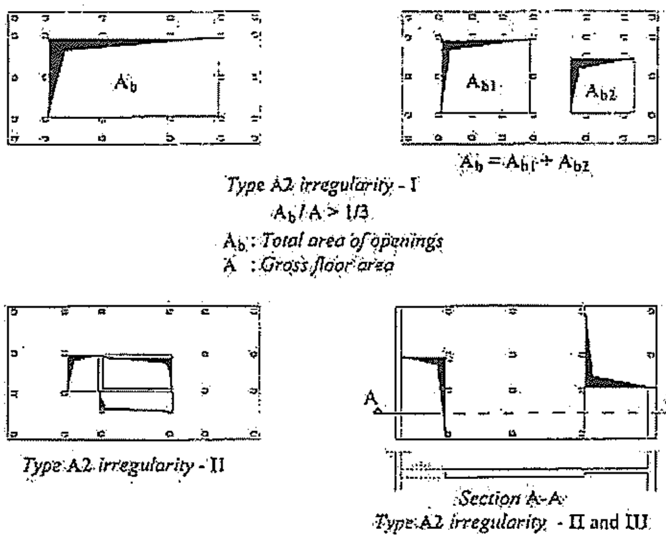


Figure 6.2

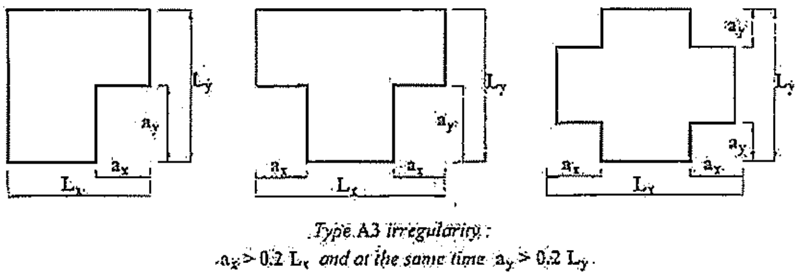


Figure 6.3

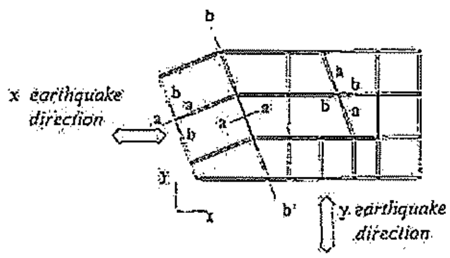


Figure 6.4

United States of America

Year: 1997
Title: Uniform Building Code. Volume 2
Division IV Earthquake Design
Current: 1997
Developing: no

Horizontal Regularity:
Table 16-M Plan Structural
1. Torsional irregularity -to be considered when diaphragms are not flexible
Torsional irregularity shall be considered to exist when the maximum story drift, computed including accidental torsion at one end of the structure transverse to an axis is more than 1.2 times the average of the story drifts of the two ends of the structure. (1633.2, 1633.2.9 item 6)
2. Re-entrant corners
Plan configuration of a structure and its lateral-force-resisting system contain re-entrant corners, where both projections of the structure beyond a re-entrant corner are greater then 15% of the plan dimension of the structure in the given direction. (1633.2.9 items 6 and 7))
3. Diaphragm discontinuity
Diaphragms with abrupt discontinuities or variations in stiffness, including those having cut-out or open areas greater than 50% of the gross enclosed area of the diaphragm, or changes in effective diaphragm stiffness of more than 50% from one story to the next. (1633.2.9 item 6)
4. Out-of-plane offsets
Discontinuities in a lateral force path, such as out-of-plane offsets of the vertical elements. (1630.8.2, 1633.2.9 item 6, 2213.9.1)
5. Nonparallel systems
The vertical lateral-load-resisting elements are not parallel to or symmetric about the major orthogonal axes of the lateral-force-resisting system. (1633.1)

Vertical Regularity:
Table 16-L Vertical Structural Irregularities
1. Stiffness irregularity (soft story)
A soft story is one in which the lateral stiffness is less than 70 % of that in the story above or less than 80% of the average stiffness of the three stories above. (1629.8.4 item2)
2. Weight (mass) Irregularity
Mass irregularity shall be considered to exist where the effective mass of any story is more than 150% of the effective mass of an adjacent story. A roof that is lighter than the floor below need not be considered. (1629.8.4 item 2)
3. Vertical Geometric Irregularity
Vertical geometric irregularity shall be considered to exist where the horizontal dimension of the lateral-force-resisting system in any story is more than 130% of that in an adjacent story. One-storey penthouses need not be considered. (1629.8.4 item 2)

4. In-plane discontinuity in vertical lateral-force-resisting element
An in-plane offset of the lateral-load-resisting elements greater than the length of those elements. (1630.8.2)
5. Discontinuity in capacity - weak story
A weak story is one in which the story strength is less than 80% of that in the story above. The story strength is the total strength of all seismic-resisting elements sharing the story shear for the direction under consideration. (1629.9.1)

Analysis:
1629.5.2 Regular Structures
Regular structures have no significant physical discontinuities in plan or vertical configuration or in their lateral-force-resisting systems such as the irregular features described in section 1629.5.3.

1629.5.3 Irregular Structures
1. Irregular structures have significant physical discontinuities in configuration or in their lateral-force-resisting systems. Irregular features include, but are not limited to, those described in Tables 16-L and 16-M. All structures in seismic zone 1 and occupancy categories 4 and 5 in seismic zone 2 need to be evaluated only for vertical irregularities of type 5 (Table 16-L) and horizontal irregularities of type 1 (table 16-M).
2. Structures having any of the features listed in Table 16-L shall be designated as having a vertical irregularity.
3. Structures having any features listed in Table 16-M shall be designated as having a plan irregularity.

1629.8.2 Simplified Static
The simplified static lateral-force procedure may be used for the following structures of occupancy category 4 or 5:
1. Buildings of any occupancy (including single-family dwellings) not more than three stories in height excluding basements that use light-frame construction.
2. Other Buildings not more than two stories in height excluding basements.

1629.8.3 Static
The static lateral force procedure may be used for the following structures:
1. All structures in seismic zone 1 and in occupancy category 4 and 5 in seismic zone 2.
2. Regular structures under 73.152 m in height with lateral force resistance provided by systems listed in table 16-N, except where section 1629.8.4 item 4 applies.
3. Irregular structures not more than five stories or 19.812 m in height.
4. Structures having flexible upper portion supported on a rigid lower portion where both portions of the structure considered separately can be classified as being regular, the average story stiffness of the lower portion is at least 10 times the average story stiffness of the upper portion and the period of the entire

structure is not greater than 1.1 times the period of the upper portion considered as a separate structure fixed at the base.

1629.8.4 Dynamic
The dynamic lateral-force procedure shall be used for all other structures, including the following:
1. Structures 72.152 m or more in height, except as permitted by section 1629.8.3 item 1.
2. Structures having a stiffness, weight or geometric vertical irregularity of type 1, 2, or 3, as defined in Table 16-L, or structure having irregular features not described in Table 16-L or 16-M, except as permitted by section 1630.4.2.
3. Structures over five stories or 19.812 m in height in seismic zones 3 and 4 not having the same structural system throughout their height except as permitted by section 1630.4.2.
4. Structures, regular or irregular, located on soil profile type Sf, that have a period greater than 0.7 second. The analysis shall include the effects of the soils at the site and shall conform to section 1631.2 item 4.

1629.9.1 Discontinuity
Structures with a discontinuity in capacity, vertical irregularity type 5 (Table 16-L) shall not be over two stories or 9.144 m in height where the weak story has a calculated strength of less than 65% of the story above.

Occupancy 4 standard occupancy
Occupancy 5 miscellaneous
Seismic zone 1 lowest
seismic zone 4 highest

Venezuela

Year: 1982
Title: Regulations for Earthquake Resistance Buildings
Current:
Developing: no

Horizontal Regularity:
6.5.1 Regular Structure Buildings
Buildings that are not included in any of the items of section 6.5.2 will be considered regular.

6.5.2 Irregular Structure Building
The building that in one or both of its main directions has one of the following characteristics is considered irregular:
b) Plan Irregularities:
b1) Large Eccentricity:
At some level the eccentricity between the shear action line in any direction, and the rigidity centre surpass 20% of the plan inertial radius.
b2) High Torsional Risk
If any of the following situations is present at any level:
i) The torsional radius in any direction is lower than 50% of the inertial radius.
ii) The eccentricity between the shear action line and the rigidity centre of a given level surpass 30% of the value of the torsional radius in any direction.
b3) Non-orthogonal System:
When an important portion of the seismic resistant system planes are not parallel to the main axis of such system.
b4) Flexible Diaphragm
i) When the rigidity in its plane is less than that of an equivalent reinforced concrete slab of 8 cm in width.
ii) When a significant number of levels have entrances with the shorter length exceeding 40% of the dimension of the lesser rectangle that inscribes the floor, measured in parallel to the direction of the entrance or when the area of such entrances surpasses 30% of the area of the aforementioned circumscribed rectangle.
iii) When the floors present a total area of internal openings that surpass 20% of the raw areas of the floors.
iv) When prominent openings exist adjacent to the important quake resistant planes or, in general, when there is lack of adequate connections with them.
v) When in any floor the length/width ratio of the smaller rectangle that inscribes such floor is more than 5.

Vertical Regularity:
6.5.1 Regular Structure Buildings
Buildings that are not included in any of the items of section 6.5.2 will be considered regular.

6.5.2 Irregular Structure Building

The building that in one or both of its main directions has one of the following characteristics is considered irregular:

a) Vertical Irregularity:

a1) Soft Story

The lateral rigidity of any story, is less than 0.70 times that of the upper story, or 0.80 times the average of the rigidities of the three upper stories. In the calculation of the rigidities the contribution of the partitions shall be included, in the case that its contribution is larger for the lower floor than for the upper floors, this could be omitted.

a2) Weak Story

The lateral resistance of any story is less than 0.70 times that of the upper story or 0.80 times the average of the resistance of the three upper stories. In the calculation of the resistance the contribution of the partitions shall be included, in the case that its contribution is higher for the lower floor than for the upper floors, this could be omitted.

a3) Irregular Mass Distribution of One of the Adjacent Levels

When the load of any level exceeds 1.3 times the loads of one of the adjacent levels. The comparison with the last roof level of the building is exempt. To verify this, the load of the appendixes will be added to the weight of the level that supports them.

a4) Systematic Mass Increases with Elevation

The distribution of loads of the building grows systematically with height. For this verification the load of the appendixes will be added to the weight of the level that supports them.

a5) Variations in Geometry of the Structural System

The horizontal dimension of the structural system in any floor exceeds 1.30 times that the of the adjacent. The case of the last level is excluded.

a6) Excessive Slenderness

The ratio between the height of the building and the lesser dimension of the structure at the base level exceeds 4. Equally when this situation is presented in a significant portion of the structure.

a7) Discontinuity in the plane of the system resistant to lateral loads

According to some of the following cases:

i) The horizontal disalignment of the axis of a vertical member, wall or column, between two consecutive floors, surpass 1/3 of the horizontal dimension of the lower member in the direction of the disalignment.

ii) The width of the column or wall in a story presents a reduction that exceeds 20% of the width of the column or wall in the story immediately above in the same horizontal direction.

iii) Columns or walls that do not continue once they reach a lower level different from the base level.

a8) Lack of Connection Between Vertical Members

Some of the vertical members, columns or walls, is not connected to the diaphragm of some level.

a9) Short Column Effect

Marked reduction in the free length of columns or walls, due to the effect of lateral restrictions such as walls, or other non-structural elements.

Analysis:

9.2 Selection of the Method

In Table 9.1 and 9.2 the method of analysis that at the least should be used are established, respectively for regular and irregular buildings, according to the classification of Article 6.5. The prescribed methods can be substituted by other more refined according to the order given in Section 9.1.

Table 9.1 Selection of the Method of Analysis for Regular Buildings
Height not exceeding 10 floors or 30 m: STATIC (9.1.1)
Height exceeding 10 floors or 30 m: IN-PLANE DYNAMIC (9.1.2)

Table 9.2 Selection of the Method of Analysis for Irregular Buildings
Vertical: a1, a2, a4, a7, a8 : SPACIAL DYNAMIC (9.1.3)
a3, a5, a6: IN-PLANE DYNAMIC (9.1.2)
On Plan: b1, b2, b3: SPACIAL DYNAMIC (9.1.3)
b4: SPACIAL DYANMIC WITH FELXIBLE DIAGRAM (9.1.4)

Yugoslavia

Year: 1981
Title: Code of Technical Regulations for the Design and Construction of Buildings in Seismic Regions
Current: 1981
Developing: yes

Horizontal Regularity:
Article 46
Suitable layout of the load bearing structures of buildings shall be achieved by means of a regular and simple floor-plan arrangement, with a uniform distribution of masses.

Article 47
Aseismic joints shall be provided in the case of:
1) buildings with irregular floor plans

Vertical Regularity:
Article 28
Analysis of structures with a particularly flexible ground floor or ant other storey may be carried out by dynamic analysis method taking into account the effect of the design and maximum expected earthquake.

Article 47
Aseismic joints shall be provided in the case of:
2) buildings or parts of buildings of unequal height

Article 49
3) abrupt changes in rigidity and strength over the height of the building aren't permitted. If the structural system includes a flexible story(s) then the building must be analysed taking into account a higher coefficient of ductility and damping.

Analysis:
Article 28
Analysis of structures with a particularly flexible ground floor or any other storey may be carried out by dynamic analysis method taking into account the effect of the design and maximum expected earthquake.