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Guidelines for disaster prevention

Volume 2

Building measures for minimizing the impact of disasters

United Nations

OFFICE OF THE UNITED NATIONS
DISASTER RELIEF CO-ORDINATOR

GUIDELINES FOR DISASTER PREVENTION

Volume II
BUILDING MEASURES FOR MINIMIZING
THE IMPACT OF DISASTERS

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FOREWORD

The Office of the United Nations Disaster Relief Co-ordinator (UNDRO) presents the first three volumes of the series entitled "Guidelines for Disaster Prevention". These volumes set forth the most basic problems in the field of disaster prevention related to physical planning, building and the management of human settlements. They are primarily concerned with the problems of new and rapidly expanding settlements in developing countries.

These publications represent the first steps at the international level to produce a clear statement of general principles and a basic set of guidelines in the field of disaster prevention in developing countries. The guidelines constitute the initial phase of a long-range programme of expansion and improvement. The reader should be aware of the limitations of their scope and terms of reference. They are not final or definitive, nor do they claim to answer the specific needs of individual countries.

The types of disasters considered are those resulting from sudden and violent natural phenomena such as floods, tropical cyclones, tsunamis and earthquakes. "Creeping" disasters, such as drought and epidemics, were excluded. However, certain man-made disasters which may result from natural catastrophes or which call for equivalent preventive measures (such as fires or explosions) were included in the present publication.

It was not within the purview of these guidelines to consider the most destructive of all man-made disasters : war. In this area, UNDRO can justifiably make recommendations and provide guidance under the heading of "post-disaster planning and reconstruction", a subject for the next set of guidelines to be published by UNDRO.

These volumes are addressed to a broad spectrum of potential users, such as policy-makers, administrators, technicians and community leaders in urban and rural areas at the national, regional or local levels. They are especially intended for government officials who have responsibility for initiating or approving development projects in high risk areas and who require an immediate and simple method of determining whether vulnerability factors and criteria and disaster risks in general have been taken into account.

Certain terms of reference were established in order to simplify and facilitate publication of the guidelines at the present stage of development. They are clearly contained within the framework of prevention. The emphasis has been on a pragmatic approach, based on the collective experience in disaster situations of those preparing these publications. Preparedness, relief and post-disaster planning and reconstruction have been intentionally omitted, since these subjects are presently being examined in several complementary studies by UNDRO.

The Office of the United Nations Disaster Relief Co-ordinator invites the users of this publication to provide the United Nations with their comments and suggestions on a continuing basis. The establishment of such a feedback and exchange of information will assist in building a comprehensive and detailed library of guidelines on disaster prevention for national and international use.

The structure of the present volumes has been adapted to the stages in the life of a settlement: the planning stage, the building stage, and the stage during which the settlements are in use, maintained, expanded or renewed. For this reason a certain overlap among the three sets of guidelines has been allowed to

be erected in areas where there is any possibility of a landslide. If buildings must be erected in landslide areas, structures of the statically determinate type are recommended.

In earthquake regions the construction of any kind of building in landslide areas should be completely forbidden.

8. LANDSLIDES

8.1 Introduction

A landslide is a down-hill movement of land on the slope of a hill or mountain.

The movement is caused by a geological instability of the slope because of heavy rain, earthquake or other influence (mining, construction, etc.).

Landslides may also happen in flatlands where there are sharp differences or fractures between land levels; e.g. in or near towns situated on high river banks, landslides may cause considerable damage. The main reason for this is that ground water level and the water content of the soil are changed by the construction and functioning of water supply and drainage systems.

The range in magnitude of landslides is great, so that general instructions on how to prevent them or halt them cannot be given.

For every landslide specific geological, morphological and soil-mechanic investigations should be carried out. In this way it will be possible to determine what building measures might be taken to stop the phenomenon from recurring.

8.2 Effect on buildings

The movement of soil causes displacement of the foundations of every structure in the area. The effect of this movement on a building depends on the size of the displacement and on the static type of structure. Statically indeterminate structures, such as multi-storey frames, shells, etc. are vulnerable to the displacement of their foundations and should therefore not

remain, since there are indeed areas of common concern among the different phases of planning, building and management. It is hoped that the cross-referencing between volumes will assist the reader. A bibliography has been included for the more specialized reader desiring to examine certain issues in greater detail.

The present three volumes were made possible with the financial support and co-operation of the United Nations Environment Programme (UNEP). They were prepared for UNDRO by Mr Sergei Bubnov, Secretary-General of the European Committee for Earthquake Engineering; Professor Adolf Giborowski, Faculty of Architecture, Technical University of Warsaw, in co-operation with Urszula Ciborowski, Architect and Town Planner; and Mr Aydin Germen, Professor, Department of City and Regional Planning, Middle East Technical University, Ankara. The volumes were completed in consultation with the League of Red Cross Societies, the United Nations Centre for Housing Building and Planning, the United Nations Environment Programme, the World Meteorological Organization, and the following panel of experts:
Messrs N. Ambraseys, Professor, Imperial College of Science and Technology, London; G. Blachère, Professor, Centre Scientifique et Technique du Bâtiment, Paris; R.B. Cardenas, Assistant Executive Secretary, Office of the President, Manila, Philippines;
G. Sebastyen, Professor, Hungarian Institute for Building Science, Budapest; and J.G. Van Putten, Secretary-General, International Union of Local Authorities, The Hague.

The Office of the United Nations Disaster Relief Co-ordinator wishes to express appreciation to all those who have contributed to these volumes for the protection of human settlements against disasters.

TABLE OF CONTENTS

CHAPTER		PAGE
	INTRODUCTION	1
1	GENERAL	6
1.1	Education	6
1.2	Building legislation	6
1.3	Building supervision	7
2	TROPICAL STORMS	8
2.1	Introduction	8
2.2	Effects on buildings	8
2.3	Building codes	9
2.4	Building protection measures	11
2.5	Maintenance	16
2.6	General precautionary measures	16
2.7	Protection against floods	17
3	FLOODS	18
3.1	Introduction	18
3.2	Protection of buildings in areas without a defence system	19
3.3	Defence system	21
3.4	Maintenance of the defence system	23
3.5	Protection of human settlements	24
3.6	Protection of houses and buildings	25
4	FLOODS RESULTING FROM THE DESTRUCTION OF LARGE DAMS	27
4.1	Introduction	27
4.2	Design of large dams	27
4.3	Observation of large dams	28
4.4	Protection of the population	29

7.9.4 Building archives

In earthquake areas archives for plans, including static and dynamic calculations for all buildings, should be created so as to enable specialists to assess the importance of 2nd or 3rd degrees of damage on the stability of buildings.

Plans from the archives should also be used for the design of strengthening and reconstruction works for buildings subjected to 4th and 5th degrees of damage.

7.9.5 Supervision

In earthquake regions effective supervision of the construction of buildings and of the testing of building materials should be provided, to ensure that the building is constructed exactly according to the design as well as to see that building materials of the quality demanded are used.

(2) Occasional cracking in reinforced concrete columns, but some cracks in brick bearing walls and more in partition walls.

(3) Some reinforced concrete columns and brick bearing walls cracked, especially in the corners of the building. No apparent displacement of the structure. No cracking in the floor slabs. Partition walls badly cracked.

(4) Small deformation in columns and walls and many cracks. Cracks in floor slabs. Small residual displacement of the structure. Repair of the building usually feasible.

(5) Large deformation of columns and walls, beyond the elastic range. Partial rupture of floor slabs. Large displacement of the whole structure. Partial collapse of the building. Repair and reconstruction usually not feasible. Building must be demolished.

(6) Total collapse of the building.

7.9.3 For buildings with the 1st degree of damage permission for further use can usually be given on the spot. For buildings with 2nd and 3rd degrees of damage, a careful examination, with additional static and dynamic analysis of the damaged structure, if necessary should be carried out before permission is given for the further use of the building.

For buildings with 4th or 5th degrees of damage, permission for use should be given only after the structure has been strengthened or reconstructed.

CHAPTER		PAGE
5	FLOODS RESULTING FROM TSUNAMIS (TIDAL WAVES)	30
5.1	Introduction	30
5.2	Protection of buildings	30
6	FIRE	32
6.1	Introduction	32
6.2	Legislation	32
6.3	Minimizing of fire risk	33
6.4	Rescue of inhabitants (architectural requirements)	36
6.5	Extinguishing fires	37
6.6	Prevention of spreading of fire	38
7	EARTHQUAKES	39
7.1	Introduction	39
7.2	Damage rating	39
7.3	Building code	41
7.4	Basic principles of aseismic design and construction	44
7.5	Building practice and structural details	46
7.6	Low-cost housing	49
7.7	Civil engineering structures	51
7.8	Education and training	51
7.9	Evaluation of damage on buildings	53
8	LANSLIDES	56
8.1	Introduction	56
8.2	Effect on buildings	56
	SELECTED BIBLIOGRAPHY	58

7.8.4.1 Foremen, clerks of works and building inspectors: these should be able to understand and follow drawings and to know how to sample and check the quality of materials.

7.8.4.2 Draughtsmen and other staff who work in the offices of architects and engineers, responsible for the detailing on the drawings and simpler calculations.

7.8.4.3 Laboratory technicians, to test the quality of materials used.

7.8.5 An earthquake is the most severe testing laboratory of all. It will reveal every fault and mistake in design and construction. Any one fault can be fatal for the people in the building.

7.9 Evaluation of damage on buildings

7.9.1 Teams of specialists for damage evaluation

To evaluate the damage to buildings resulting from an earthquake, a team of skilled specialists (civil engineers) should be formed. Immediately after the earthquake, the specialists should visit all seriously damaged buildings to evaluate the degree of damage and to give permission, if possible, for further use of the building.

7.9.2 For the evaluation of damage, the following classification systems could be adopted.

Degree of damage:

(1) Some cracking in the masonry partition walls, but infrequently in brick bearing walls. Some plaster spalling.

7.8.1 all architects, who should be aware of:

7.8.1.1 - the basic principles of designing in seismic areas;

7.8.1.2 - enough knowledge of structural design to understand and use what their structural engineers advise;

7.8.1.3 - which details are important and should be incorporated in drawings and checked on site during inspections;

7.8.2 and all civil engineers who should know:

7.8.2.1 - the principles of structural design and construction for buildings and other engineering structures to withstand earthquake induced loads, with minimum drainage;

7.8.2.2 - the principles of engineering seismology and soil-structure interaction;

7.8.3 for the design of important structures, if no earthquake engineering specialists are available in the country concerned, consultants from abroad could be invited to check designs submitted.

7.8.4 Training at the sub-professional level

Training of sub-professional men who also work on the construction of buildings and other civil engineering structures in earthquake areas is as important as the education of architects and engineers. The earthquake resistance of buildings and structures depends not only on the design, but also on the quality of the construction, which is supervised by sub-professional men.

Men of the following professions should have special training for operating in earthquake regions:

INTRODUCTION

The Office of the United Nations Disaster Relief Co-ordinator (UNDRO) has placed the highest priority on planning and prevention because of the dual phenomena of rapid urbanization and the high rates of population growth, particularly in the developing countries. According to United Nations estimates, more than 50% of the world's population will be living in urban areas by the year 2,000. Between the present time and the end of this century, mankind will probably have to provide as much shelter and related facilities as during the whole of past recorded history. Whereas most countries in the developing world double their national populations every 25 to 30 years, the same countries double their urban populations every 12 to 15 years and, in the case of the urban poor living in slums and squatter settlements, there is often a doubling of population every 7 years or less. The sheer magnitude of the human problem in disaster-prone areas, especially the rapid expansion of these settlements and the concentration of population in them, indicates that relief measures and post-disaster action are by themselves not sufficient.

The essential aim of the guidelines is to assist the international community to take the first co-ordinated steps to prevent or at least to mitigate disasters. During the last two decades, the world public has become increasingly alarmed by disasters, which have tended to become more and more destructive as they affect ever larger concentrations of population. The response of the international community has been focussed primarily on relief actions; however, it is now realised that the actual and potential consequences of disasters are so serious and increasingly global in scale, that much greater emphasis will henceforth have to be given to planning and prevention.

UNDRO's objective in the broad field of pre-disaster planning is to promote the prevention, control and prediction of natural disasters. All its activities are based on three findings : (a) that disasters constitute a major development problem for most disaster-prone countries; (b) that most disasters can be prevented; and (c) that the most basic preventive measures are also the least expensive.

Although detailed statistical data on disaster damage are still very scarce, it is known that the damage caused by disasters greatly exceeds the total amount of assistance - both bilateral and multilateral - which disaster-prone developing countries receive from abroad. In terms of percentage of their gross national product, the losses caused by disasters in many of these countries more than cancel out any real economic growth. To cite one example, the Office of the United Nations Economic Commission for Latin America (ECLA), in Mexico, estimated that in the five countries of the Central American Common Market, disaster damage has averaged 2.3% of the gross domestic product in the fifteen year period 1960-1974. This figure does not take into consideration a number of indirect effects, such as higher incidence of certain diseases, or many small events such as limited floods which, taken on aggregate, may have disastrous effects. Since the countries concerned also have a population growth rate of about 3% a year, to avoid an actual decline in the rate of economic growth or remain at a static level of development, they must achieve an economic growth rate of at least 5.3%. Very few of these countries actually achieve this rate and, partly because of disasters, many are actually losing ground in relative terms. This fact clearly indicates that disasters should be viewed as a problem of economic development and that, as with all such problems, they should be resolved in a systematic manner by concerted action beginning at the level of national planning. It is this simple observation that has promted UNDRO to

7.7 Civil engineering structures

7.7.1 Water-supply

The normal functioning of the water-supply system after an earthquake is important not only for domestic supply, but more so for the operation of fire-extinguishing equipment, since many fires break out following the disruptive effects. It is recommended that in earthquake regions flexible waterpipe junctions, capable of following the soil vibrations without rupture, should be used.

7.7.2 Bridges

After earthquakes the establishment of normal traffic flow is important for the evacuation of population as well as for bringing necessary assistance. Usually bearing structural members of bridges have good earthquake resistance if bridge supports are sufficiently well secured against lateral sliding. Designers of supports for bridges in earthquake regions should consider this fact.

7.7.3 Dams

The rupture of a high dam as a result of an earthquake can cause disastrous flooding in the downstream area. The design of high dams in earthquake regions should take into account the seismic loads, having in mind the fact that new reservoirs can also cause earthquakes because of additional water pressure on the land surface.

7.8 Education and training

In countries subject to earthquakes, special training is required at professional levels for:

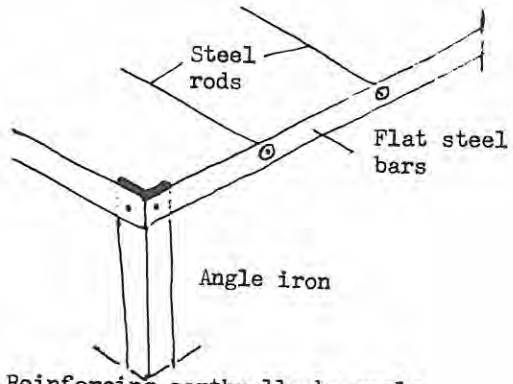
7.6.3 A complete change of construction practice for low-cost housing is a very difficult economical problem for developing countries. Millions of people are living and will still live in houses which are very vulnerable to earthquake loads. Nevertheless, a long-term programme for the strengthening and reconstruction of houses not resistant to earthquakes should be prepared by the countries involved.

The programme in the most active earthquake regions should initially include:

7.6.3.1 - the placing of lightweight roofs (wood, Ytong, Siporex, plastic) instead of heavy roofs;

- the strengthening of outside bearing walls by the construction of vertical and horizontal tie bands (many techncial solutions are available).

7.



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Reinforcing earthwalls by angle irons and steel bars

propose an "international strategy for disaster prevention".

Many disasters - considered as distinct from the natural phenomena which cause them - can be avoided. Virtually all natural phenomena liable to cause disasters share one common feature: although it may not be possible at the present stage of scientific knowledge to forecast <u>when</u> they are going to happen, (except for a few hours beforehand in some cases), it is often possible to predict with a reasonably high degree of accuracy <u>where</u> they are most likely to occur, for example, in flood plains, seismic areas or avalanche corridors. Even in the case of such 'erratic' phenomena as tropical storms (hurricanes, cyclones and typhoons,) it is known that some 90% of the human losses and damage are attributable to the action of water and not to the effects of wind.

This conclusion has obvious implications for the location of human activities of any kind. There is nearly always a choice that can be made between a dangerous site and a <u>less</u> dangerous one. Such a choice can be encouraged or even imposed by measures whose cost is negligible if taken in time. Examples would be the adoption and application of town and country planning laws and zoning regulations based on vulnerability studies. The key to ensuring that the best choice is made is to include in the appropriate development projects a vulnerability analysis of the region affected. Whereas expenditure on such a study is negligible in comparison with the total cost of a major development project, the 'multiplier effect' of such a preventive measure is enormous, both in terms of human lives saved and damage avoided, and from the point of view of the savings in aid which might otherwise have gone into relief and reconstruction. This is a particularly justifiable strategy at a time when the most disaster-prone developing countries are undergoing rapid demographic expansion and urbanization. Errors committed now will be all the more costly to

correct later. The massive investments needed to develop the infrastructure of human settlements can be safeguarded by planning and prevention based on vulnerability analyses.

Although it has been demonstrated that much can and should be done in disaster prevention, some countries are afflicted with a sense of fatalism about natural disasters, which acts as a brake to development as a whole. Such a sense of fatalism has often arisen because of the enormity of the problem and the accumulated burden of successive disasters, compounded by the lack of resources to plan for timely assistance in emergency situations. Nevertheless, Governments bear the basic responsibility for action with respect to disasters, not only in post-disaster situations but also at pre-disaster stages. They should initiate appropriate measures and promote a national consciousness of - and active interest in - disaster prevention. Governments in many countries should also adopt measures designed to improve the disaster relief machinery.

Mention should also be made of the role of dissemination of information, training, warning for disaster prevention, and community preparedness. The education of the public can begin at the primary school level and should be extended to many skilled and unskilled professional categories, including construction workers and others. The application of preventive policies, plans and measures could be considerably facilitated through legislation. Governments should assume greater initiative in such legislation in the field of prevention, particularly regarding land use and other locational aspects of physical planning and building.

UNDRO is currently undertaking a comprehensive study on the state of existing knowledge in disaster prevention and mitigation, which will identify firstly, the existing expertise which may be applied directly in developing countries and, secondly, the gaps

7.5.6 During an earthquake the partition walls of a building are also subjected to the earthquake loads. Since their failure may cause casualties, the execution of partition walls and their connection with bearing walls should be carried out very carefully.

7.6 Low-cost housing

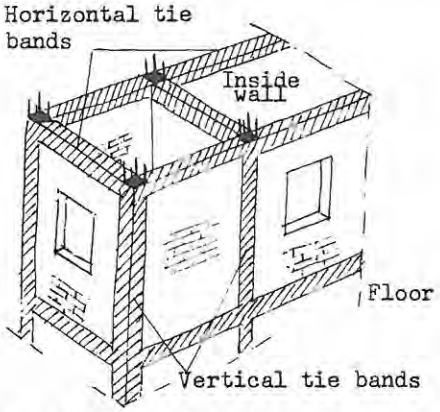
In areas where low-cost one-floor houses are the majority form of accommodation, more than 90% of all earthquake victims perish in them. Special attention should therefore be paid to the construction of these houses.

The same basic principles of design and construction, as well as the same building practice and structural details, apply to these houses as for other buildings.
(See paras 4 and 5.)

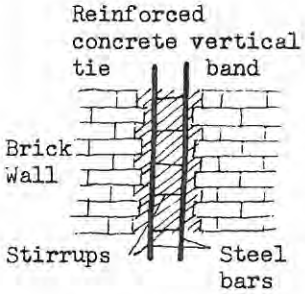
7.6.1 Heavy, flat roofs or domes of clay or abode often fall during earthquakes, killing many people sleeping or resting in the houses. Outside bearing walls, which are usually made of clay or abode, are not able to follow the vibrations caused by the earthquake because of their brittleness. Their deflections cause the failure of roofs. Failure of such houses has caused many tens of thousands of deaths in Iran and Middle Asia.

7.6.2 Houses build according to the "Taquazal" system, consisting of vertical wooden studs connected together by nailing on horizontal wooden laths, filling in between with clay and stones, have similar behaviour. This system is widely used in Central and South America for rural houses. The failure of houses of this kind caused many deaths during the Managua earthquake (1972) and during other earthquakes in Central and South America.

concrete, the wall panels being filled in with brick or stone. The horizontal beams should be at the level of the floor slabs and tied to them. The vertical columns should be constructed at the corners of the external walls and at the junction of inside bearing walls with the external walls. (See drawing).



Horizontal and vertical tie bands



Detail of the connection of reinforced concrete band and brick wall

7.5.4 Multi-storey buildings without such framing are liable to massive collapse, causing hundreds of deaths. They are unsuitable for seismic zones. Such buildings are a dominant and traditional type in many lands. There were some hundreds of them in the modern part of Skopje in 1963; nearly 50% were damaged beyond repair. A number of large tenement buildings collapsed, causing from 50 to 200 deaths in each.

7.5.5 Recent research work on the evaluation of earthquake damage has shown that for reinforced concrete frame structures the spacing of stirrups in the columns at their junctions with the beams should be decreased. This does not present any economic problem.

which require concerted action by the international community. This study, which includes varied subjects such as seismology, vulcanology, meteorology, hydrology, land use, building and civil engineering, health, public information, and the economic sociological and legal aspects of disasters, will provide the qualitative data necessary for the formulation of the international disaster prevention strategy mentioned above. Another study now in progress is a world-wide survey of the damage, both direct and indirect, caused by disasters. The objectives are to provide the quantitative data necessary for the formulation of the strategy and to enable disaster-prone developing countries to formulate their own long-term prevention policies and to carry out cost-benefit analyses of various alternative preventive measures.

There are many additional areas where planning, prevention and preparedness measures can be taken. A particularly important area is the field of education in disaster preparedness and prevention and the establishment of prediction and warning systems. However, the first and most basic problems in the field of disaster prevention are those related to planning, construction and the management of human settlements.

1. GENERAL

Buildings and other structures in disaster-prone areas may be subjected to abnormally heavy loads as a result of the action of horizontal and uplifting wind forces (tropical storms), water pressure and hydrodynamic forces (tropical storms and floods), and vibrational forces (earthquakes). In some cases these loads may be large enough to cause the destruction of buildings, with the consequent loss of life and material damage to property. For this reason special attention must be paid to the design and construction of buildings and other civil engineering structures in disaster-prone areas. Prevention or at least diminution of the disaster effect could be achieved by:

- education
- building legislation
- building supervision

1.1 Education

Education in disaster prevention measures should begin at school by informing pupils about disaster effects and methods of protection against disaster. In civil engineering departments of universities and technical institutes the design of buildings subject to special loads, and their construction, should be treated as separate subjects.

1.2 Building legislation

Building codes and regulations for disaster-prone areas should define the special loads which should be taken into account when designing buildings for these areas. Up-to-date methods for the structural analysis of buildings and other types of structure should also be promoted.

7.5.2 Brick and stone structures are very sensitive to earthquake loads, especially if the mortar is of poor quality, since the rupture of brick and stone walls usually occurs through the joints. Thus the use of good lime or lime-cement mortars in earthquake regions is strongly recommended.

The mortar should not be too wet; the joints should be thin, not exceeding 1cm., and should be completely filled with mortar.

Proper bonding techniques are of critical importance and should be used at external corners, at the intersection of cross walls, and at door and window openings.

In minor or moderate seismic conditions, the height of the structure should be limited to two floors. In severe conditions, the wall should be reinforced with vertical steel bars at the external corners, and the junctions with cross walls; also with horizontal strips of welded wire fabric embedded in the mortar joints at intervals not exceeding 500mm in height.

In minor seismic conditions, buildings of more than two floors should have vertical reinforcement at the corners as described above, and ring beams of reinforced concrete at each floor level. The floors should be of reinforced concrete tied into the ring beams. Wooden floors cannot provide the desired connection of all bearing walls which is needed to ensure that they resist the earthquake loads together.

In moderate or severe seismic conditions, multi-floored buildings of three storeys or over should be fully framed with conventional beams and columns of reinforced

7.4.6 Special attention should be paid to the design and construction of staircases in the building, since at the beginning of an earthquake the inhabitants will immediately try to leave the building by the stairs. Thus the staircase structure should be safe enough to withstand seismic loading without failure.

7.4.7 Earthquakes can cause differential settlement of foundations and even liquefaction of soil deposits in some cases, which may cause the failure of the structure. For more important buildings in earthquake regions a geological survey of the site should be carried out in order that earthquake resistant foundations can be designed. Old watercourses or ponds which have been filled in, are a special hazard and need deeper foundations.

7.4.8 Analysis of the effects of recent earthquakes have shown that elastic structures (tall buildings) have better earthquake resistance on firm soil than on soft soil.

7.5 Building practice and structural details

7.5.1 The building technique used and structural details should ensure the transmission of horizontal forces through all structural components from the soil to the roof.

Monolithic reinforced concrete shear walls or frame structures and steel frame structures have good earthquake-resistant properties. For reinforced concrete systems using precast elements, joints should be designed so that corresponding horizontal forces can be transmitted without rupture.

1.3 Building supervision

The construction of buildings and other types of structure should be strictly supervised to ensure that they are built exactly in accordance with the approved design, with the use of materials of sufficient quality and with appropriate construction techniques.

2. TROPICAL STORMS

2.1 Introduction

Moving storms of tropical origin are called cyclones in the Indian Ocean, hurricanes in the Atlantic Ocean and typhoons in the Pacific Ocean. In the text which follows, this natural phenomenon is called a tropical storm.

2.2 Effects on buildings

During a tropical storm the air, moving at high speed, becomes a very destructive agent, mainly because of the force exerted by the wind itself, but also because of solid objects which are carried along with it. In tropical storms increased levels as well as torrential rainfall cause water to become the agent of destruction.

Buildings in coastal areas are sometimes subject to these destructive forces simultaneously. Thus tropical storms cause damage through both flooding and wind.

During tropical storms wind searches for and reveals every structural flaw in a building. The most wide-spread damage occurs to small buildings. Faulty details and faulty construction practices are the cause of many building failures. Roofs are blown off, usually as a result of insufficient anchorage. Glass in windows and lightweight walls are blown out because they are subjected to positive pressure acting outwards from inside the building and to strong suction forces caused by the wind outside the building. The importance of bracing and stiffening is apparent.

Extensive damage is caused to electricity supplies by the destruction of overhead power-lines. Short circuits may cause fire hazards.

recommended that structures in seismic regions should be designed to be as light as possible.

7.4.2 Earthquakes induce vibrations in a structure. Vibration amplitudes depend upon the elastic characteristics of the building materials used and upon the position of the centre of gravity of the structure. To minimize the amplitudes and thus the deformation of the structure, the centre of gravity should be kept as low as possible.

7.4.3 Energy released by the earthquake and transmitted to the structure should be absorbed by the structure without serious damage. For better absorption of energy building materials when properly used should be ductile, such as: steel, reinforced concrete, wood or plastic. These materials are also relatively light in weight and thereby reduce earthquake loads.

7.4.4 To avoid the torsional effect of earthquake loads it is recommended that buildings be designed with simple and symmetrical floor-plans (lay-out of the bearing elements in plan).

7.4.5 If parts of a building are of a different height or have differing dispositions of bearing elements then each part will have a different type of vibration. In this way supplementary mutual loadings are transmitted from one part of the building to another, causing damage to the weaker part of the building. Thus the parts of a building of different height or having different dispositions of bearing elements should be separated by gaps.

strongest probable earthquake, so that loss of life may be avoided.

7.3.1.4 Techniques for earthquake-resistant construction using various building materials are given below (see paras 4 and 5).

7.3.2 Seismic investigations

In regions of high seismic activity, a detailed geotectonic and seismic survey of the region should be carried out in order to determine the most active and consequently the most dangerous areas, where the safe construction of buildings is of particular importance. The fact that the impounding of reservoirs may sometimes induce earthquakes should be taken into account.

7.3.3 Effects of local geological conditions on intensity

Local geology, morphology and hydrogeology and earthquake mechanisms influence the intensity of the seismic loadings. The intensities given on a seismic zoning map give an average earthquake intensity to be expected in the region. For important structures a more detailed study of the site effect of intensity may be carried out. This will require up-to-date seismic methods including any available strong-motion records for the site, and also taking into account the site geology and the vibrational characteristics of the structures to be built there.

7.4 Basic principles of aseismic design and construction

7.4.1 Since the earthquake forces which act on structures are proportional to the mass of the structure it is

Flooding in coastal areas may be caused by the sea rising several meters above normal levels. Severe flooding, both near the coast and further inland, is caused by the combination of torrential rain and a simultaneous rise in sea level. Water backs up in streams and drainage ditches and thus prevents or retards normal drainage processes.

2.3 Building codes

2.3.1 Wind Loading

For the design of buildings in tropical storm areas, the wind load should be considered as a primary load; it should be taken into account together with the other primary loads (dead loads, live loads, impact loads, earth-pressure, and loads resulting from temperature changes). Earthquake loads are not included in this list. Building designs should be checked for wind and earthquake forces acting separately; it is assumed that the two do not act simultaneously.

All wind loads are dynamic loads in the sense that they result from the effect of moving fluid, but in order to simplify design, static loads of value equivalent to the dynamic loads are assumed to act. This assumption is not justified for certain types of wind-sensitive structures such as free-standing towers, high chimneys and suspension bridges.

Building codes should determine the wind loading to be taken into account for the static and dynamic analysis of structures under wind loads. The following factors must be considered:

- wind velocity
- shape factor
- gust factor
- height-velocity relationship
- suction effect

2.3.2 Design for storms

The intensity of the wind and thus wind loadings depend on the storm area and on the design period considered. The longer the considered design period, the stronger is the wind effect which could occur during that period. The design storm strength should be determined in accordance with the importance of the building under consideration. For the most important buildings (nuclear power plants, hospitals, public buildings etc.) the design for wind loads should be such that the probability of exceeding them during the lifetime of the structure will be minimal. For less important buildings, a lower margin of safety may be used. When calculating design storms, the area which would be flooded in different periods, as well as the depth of the floodwater, should be determined.

2.3.3 Building materials

In tropical storm areas the following building materials and construction techniques are likely to augment damage; and if possible should be avoided:

- walls of unburnt earth bricks or blocks
- clay mortar
- wattle and daub walls
- thatch or leaves, in roofing or otherwise

resilience of the building concerned, and the various modes of vibration (usually the first mode is critical) determined by the vibration equations of one or more multi-mass pendulum systems.

This method requires specially trained experts and in the case of multi-mass systems the use of computers.

The building code should also determine the influence of soil conditions on seismic loads. Buildings on soft soil usually suffer greater damage than buildings on firm soil. Seismic vibrations in soft soil tend to damage tall, slender structures more than rigid structures. In soft soil damage is augmented by the differential settlements of the structure, which occur before, during and after an earthquake.

7.3.1.3 Required safety factor

The safety factor required by the building code for structures subject to seismic loading should depend on:

- the economy of the country
- the return period of strong earthquakes in the region and their characteristics
- the relative importance of the building
- local building techniques, building materials, and efficiency of supervision.

The basic principle of safety factor requirements in the building code should be that neither the whole structure nor any of the individual bearing components (roof, floor-slabs, bearing walls) should fail during the

Seismic zoning maps should be prepared and based on historical data of past earthquakes in various areas and/or on the results of geotectonic and seismic investigations of these areas.

7.3.1.2 Seismic loads and methods of analysis

Since earth movements in an earthquake occur in a random fashion, forces induced by it act on buildings in all directions.

The most dangerous component of these forces for the stability of ordinary buildings is the lateral one.

It is generally assumed that earthquake and wind forces act separately. For comparatively low, rigid buildings (of brick or stone) the assumption can be made that the acceleration of all parts of the building conforms with that of the ground at its base.

The acceleration ("a") multiplied by the mass of the structure (mass = weight/g) can be transformed into a force ("F") by the equation:

$$F = \frac{a}{g} \cdot W = K \cdot W$$

K is called the "seismic coefficient" and depends on the acceleration to be expected in any particular seismic area. Its value in various published codes lies in the range 0,025 to 0,35, depending on the intensity of the earthquake to be expected and on the soil conditions in the area. To simplify the analysis the horizontal forces acting at each floor level can be considered. This method of analysis is called the "static method". For tall, slender structures the "dynamic method" of analysis should be applied, taking into account the

2.4 Building protection measures

2.4.1 Design of small buildings

The most vulnerable structures in tropical storm areas are normally small buildings. The majority of smaller buildings are designed for gravity loads only so that wind forces are taken into account - in the case of taller structures only - as horizontal static forces, whose values depend on the climatic zone. Tropical storm wind forces sometimes act vertically upwards from the bottom of the building towards the top, thus creating a lifting force on various components of the structure.

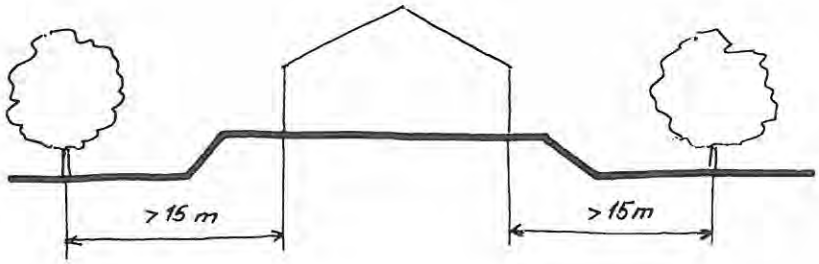
In coastal areas, where high tidal surges are likely, buildings should be constructed at higher elevations or on "pole-type" substructures with timber piles or poles, or on concrete piles or columns embedded in the ground so that the first floor of the structure is sufficiently elevated above high water level. It should be borne in mind that this type of structure may accentuate wind damage.

The following points should be taken into account when trying to improve the security of small buildings in tropical storm areas:

- raising of the ground level, if possible, to protect the building from inundation
- the selection of good foundation soil which does not lose its bearing capacity even when inundated
- protecting buildings by planting trees not less than 15 m from the building
- minimizing the use of low pitched and flat lightweight roofs

- utilizing heavy materials as much as possible
- minimizing the use of overhangs, canopies etc.

Protection by raising the ground level
and planting trees



- preventing uplift of the building

Wrong Better

Many buildings of reinforced concrete or steel suffer heavy damage, and a few partially collapse. Monuments fall; heavy damage occurs to water tanks and pipelines.

7.2.5 Intensity X (annihilating earthquake):

Most buildings collapse totally. Only a few buildings of reinforced concrete or steel partially collapse or are heavily damaged; heavy damage to bridges. All underground structures are destroyed.

7.3 Building code (see Manual on Management of Human Settlements)

7.3.1 For design and construction in seismic regions special building codes should be prepared. The code should determine:

- a seismic zoning map, which should be revised and up-dated periodically;
- seismic loads and methods of analysis, also to be revised periodically
- required safety factor for different types of engineering structures;
- techniques for earthquake-resistant construction using various building materials and methods of construction.

7.3.1.1 The seismic zoning map, determining the earthquake intensity to be expected in any particular area of the country, with some predetermined probability is the basis for calculation of seismic loads to be taken into account when designing dwellings and other structures.

A few reinforced concrete, steel, and well-constructed wooden buildings suffer only slight damage (thin fissures in the plastering). The remainder of such buildings are undamaged.

7.2.2 Intensity VII (very strong earthquake):

Most buildings of unburnt brick (abode) suffer heavy damage (large fissures in the bearing walls, chimneys fall down). A few buildings of this quality partially collapse.

Most brick, stone, and standard wooden structure buildings suffer slight damage (thin fissures) but many buildings of this type suffer moderate damage (pieces of plastering fall down, thin fissures appear in bearing walls, etc.)

Many buildings of reinforced concrete or steel suffer slight damage, but a few remain undamaged.

7.2.3 Intensity VIII (destructive earthquake):

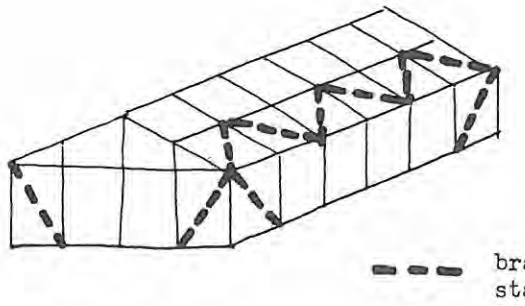
Most buildings of unburnt brick partially collapse; many collapse totally. Most brick and stone buildings suffer heavy damage (large fissures in the bearing walls) and a few partially collapse.

Many reinforced concrete or steel buildings suffer moderate damage, others only slight damage. Monuments are displaced, and pipelines partially broken.

7.2.4 Intensity IX (partially annihilating earthquake):

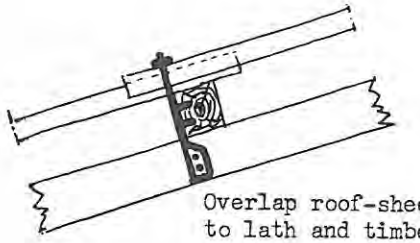
Most buildings of unburnt brick collapse totally; only a few partially collapse. Many buildings of brick and stone partially collapse and a few collapse totally.

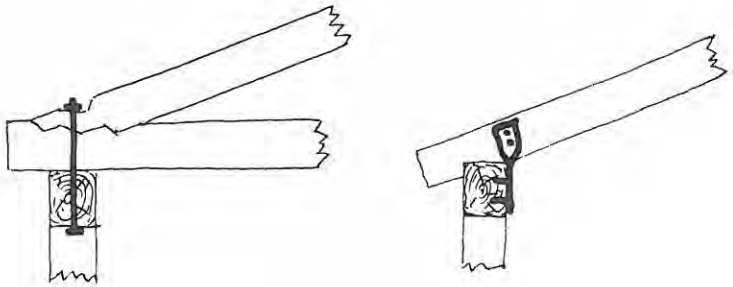
- providing bracing for stability (important for hall-type buildings such as schools, etc.)



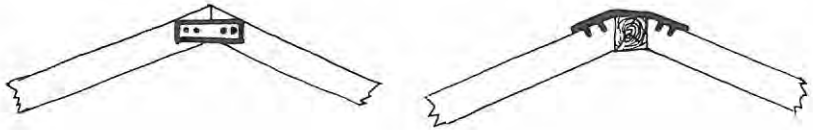
2.4.2 Structural details (Examples)

Most small buildings in tropical storm areas are light wooden structures. All elements of these buildings should be well-anchored and connected together: tiles onto laths, laths onto rooftruss timbers, rooftruss onto purlins, purlins onto wall-frame, wall-frame onto foundations.

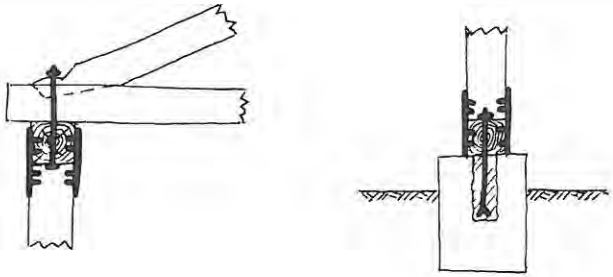




Connection of rooftruss to purlins



Connection in roofpitch



Connection of purlin to the wall-frame
and the wall-frame onto the foundation

7. EARTHQUAKES

7.1 Introduction

Earthquakes cause vibration of the soil which, transmitted to buildings and structures, induces horizontal, vertical, and torsional dynamic loads.

Magnitude is a measure of the energy released in the form of vibration by a particular earthquake.

Intensity is the seismic effect of an earthquake at a given place on man-made structures and on the ground itself. At present the following intensity scales are widely in use: the MSK (Medvedov-Sponheuer-Karnik) Scale, whose general adoption has been recommended by UNESCO, and the MM (Modified Mercalli) Scale. Both scales have 12 degrees of earthquake intensity. Moderate damage depending on the type of dwelling may be caused by an earthquake of intensity in excess of VI or VII.

7.2 Damage rating

The effect of an earthquake on buildings depends on the earthquake intensity.

The following general effects on man-made structures may be expected to be associated with different intensities:

7.2.1 Intensity VI (strong earthquake):

Many buildings of unburnt brick (abode) and a few buildings of brick, stone, and standard wooden structure suffer moderate damage (some pieces of plastering fall down; thin fissures appear in load bearing walls, serious cracking occurs in partition walls, cracks appear in chimneys, some parts of chimneys fall down).

6.6 Prevention of spreading of fire

6.6.1 Long buildings should be provided with fire-resistant walls without openings (or with openings closed by fire-proof doors) at a spacing of not more than 40 m.

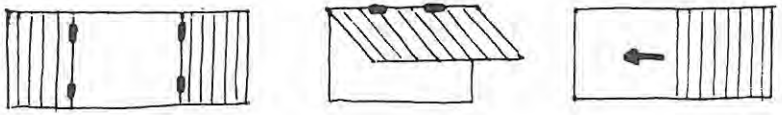
6.6.2 Where buildings have no fire-resistant walls the space between buildings should correspond to the height of the building, if possible.

6.6.3 Fuel tanks and other easily flammable material should be located so that they lie behind the buildings and settlements, when viewed from the direction towards which the prevailing wind blows.

2.4.3 Protection of windows

When window-glass is broken, the storm wind gains easy access into rooms, causing uplift pressures on roofs and possible destruction of the entire building. The protection of windows by means of shutters is a very important measure in minimizing the effect of storms on buildings.

Windows can be protected by non-removable shutters:



Side-hinged Top-hinged Sliding

or by taking temporary protection measures:

Boarding up with planks

Fixing bamboo, wood-strips or electrical and medical tape strips to the frame

For windows it is recommended that the use of large glazed areas be minimized. The use of mullions is to be encouraged since added support is provided and easy replacement is possible at a lower cost if the glass is broken.

Window frames should be well-anchored into the walls.

Windows and outside doors should be constructed so as to be strong enough to resist wind gust effects.

2.5 Maintenance

In order to prevent houses being destroyed because of the deterioration of some structural elements which might fail during a storm, all building elements should be kept in good condition by maintenance.

- wood should be protected against decay by painting, and against fungi and termites by the use of insecticides
- metal strips and anchors should be protected against corrosion by painting.

Parts in bad condition should be replaced before the start of the tropical storm season.

2.6 General precautionary measures

In storm-prone areas the following general precautionary measures should be taken before the start of the tropical storm season.

2.6.1 Loose coverings such as roof tiles should be secured and window shutters repaired.

2.6.2 Dead or dying trees should be removed and movable objects should be anchored to the house or put under a storm net.

building is accessible only from one side its depth should not exceed 20 - 25 m according to the length of the water-jet. If the building is accessible from two sides its total depth should not exceed 40 - 50 m.

6.4.7 For fire protective purposes, rectangular building shape is more favourable than a square one (with the same surface area in each case), because of better accessibility. Buildings with large square floor-plans should be provided with an inside court.

6.4.8 In earthquake areas the streets should be wide enough to make the access of fire-engines possible, even if part of the street is blocked by the wreckage of collapsed buildings.

6.5 Extinguishing fires

6.5.1 Important buildings with many occupants should be equipped with fire warning systems. The functioning of this system should be regularly tested.

6.5.2 A suitable system of hydrants inside the buildings and on the streets should provide enough water for fire-extinguishing purposes at all times.

6.5.3 The fire station should be equipped with scaling-ladders whose height corresponds to the height of buildings in the town (with the exception of very tall buildings).

6.5.4 In earthquake areas fire-extinguishing equipment (fire-engines and cars, pumps, scaling-ladders etc.) should be kept in earthquake-resistant garages and storehouses or in the open air, in order to be available for use immediately after an earthquake occurs.

6.3.5 Buildings that house large numbers of people (i.e. theatres, cinemas, schools), buildings where the movement of people is restricted (i.e. hospitals, prisons), and buildings essential for the social and economic life of the community require special precautions and receive separate treatment in fire regulations.

6.4 Rescue of inhabitants (architectural requirements)

6.4.1 For the speedy evacuation of inhabitants or other users, the building should have at least two exits. The number of exits needed depends upon the number of people and the purpose the building serves.

6.4.2 The building should be provided with a vestibule with two separate pairs of doors to cut off the staircase from the exit doors. This should prevent the staircase acting like a chimney during a fire. The fire resistant capacity of the inside staircase should be at least 2 hours.

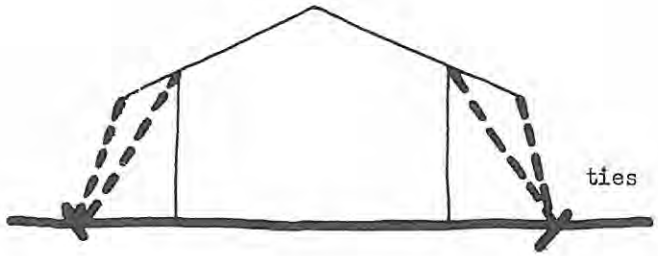
6.4.3 Tall buildings should have separate fire escapes. Large and tall buildings, in particular present special problems which require appropriate consideration in drafting legislation. This is particularly important in regard to the rescue of their occupants.

6.4.4 The building should be accessible to fire fighting equipment from at least two sides.

6.4.5 Around the building there should be enough space to erect a scaling-ladder. The higher the building the more space is needed.

6.4.6 The depth (breadth) of the building should facilitate the full use of water-jet fire-extinguishing equipment. If the

2.6.3 The building and the roof should be securely tied down.



2.6.4 A supply of boards, storm-shutters and timber for boarding windows and bracing outside doors should be maintained.

2.6.5 Free standing signs and posters should be tied down and/or perforated.

2.7 Protection against floods

Protection measures for buildings against floods which accompany tropical storms are given in the "Floods" section of this manual.

3. FLOODS

3.1 Introduction

In recent times the greatest loss of life in natural disasters has been inflicted by floods caused by heavy rain, tropical storms, and tidal waves. In order to minimize the impact of flood disasters, special attention should be paid to the following measures:

- technical protection of inundation areas (use of dikes, embankments, temporary reservoirs etc.)
- protection of houses and buildings in the area

Man's interference with natural phenomena, such as tree-felling, the urbanization of large areas, and the construction of sewage and water regulation systems, has changed the hydrological regimen of some areas. One effect is that in some regions rainwater now runs away more quickly, and for this reason high water-levels in water-courses occur sooner.

It is important that existing defence systems of protected areas should function well, since in these areas the population is relatively dense and more goods are accumulated, partly as the result of a feeling of greater security by the people.

For most areas increasing security against inundation is mainly a financial problem and the problem of adequate supervision of the safety of the project. For the regulation of watercourses and the construction of a defence system (embankments, equipment) considerable finance

CLASSIFICATION OF FIRE RESISTANCE OF BUILDING COMPONENTS

Category of building fire resistance	FIRE RESISTANCE CAPACITY IN HOURS						
	Bearing and staircase walls	Filling of the framework	Columns	Floors (slabs)	Partition walls	Roofs	Fire-breaks
I.	4 fireproof	1 fp	3 fp	1,5 fp	1 fp	1,5 fp	5 fp
II.	2,5 fp	1/4 fp	2,5 fp	1 fp	1/4 fp	1/4 fp	5 fp
III.	2 fp	1/4 fp	2 fp	3/4 not easily combustible	1/4 n.e.c.	- combustible	5 fp
IV.	1/2 n.e.c.	1/4 n.e.c.	1/2 n.e.c.	1/4 n.e.c.	1/4 n.e.c.	- combustible	5 fp
V.	- combustible	- combustible	- combustible	- combustible	- combustible	- combustible	5 fp

- by providing a sufficient layer of concrete between the outside surface and the steel bars (increasing the thickness of the protective layer of concrete from 1.25 cm to 2.5 cm, so that the time taken for the steel bars to reach the temperature of 430 - 470° C is increased from 30 mins to 1 hour).

6.3.3 The fire resistant capacity of every building should be analysed using the local standard fire diagram and the fire resistant capacity of the structural elements should be tested in the laboratory for various times of exposure to a standard fire, during which:

- the structural element should not collapse
- the fire should not break through from one side to the other
- the temperature of the non-exposed side of the structural element should not exceed 140° C (average)or 180° C (maximum).

The fire resistant capacity of a building could be classified according to the resistance capacities of its structural elements as shown in the chart on page 35.

The fire resistance category of a building should conform to the purpose of the building and the fire protection equipment installed.

6.3.4 Activities which may cause explosions or blasts should not be permitted in blocks of flats or in other buildings where many people are present at one time.

is needed. Advantages to be gained from this kind of investment should be carefully compared with investment costs (cost-benefit analysis).

3.1.1 Water loads

For the design of structures and buildings subject to water pressure the following loads should be taken into account:

3.1.1.1 Hydrostatic loads, which can act vertically on horizontal surfaces, or laterally on vertical surfaces. Inclined surfaces are subject to both vertical and horizontal load components resulting from hydrostatic pressure.

3.1.1.2 Uplift loads which act in a vertical direction on the underside of horizontal or sloping surfaces of buildings or structures.

3.1.1.3 Hydrodynamic loads that are induced on buildings or structures by the flow of flood water. Hydrodynamic loads can be converted to equivalent hydrostatic loads.

3.2 Protection of buildings in areas without a defence system

If no defence system for protection against floods exists in the area to be protected, the following provisions should be made:

3.2.1 A study of inundation in the area should be carried out, using up-to-date hydrological and statistical methods.

The following factors should be taken into account:

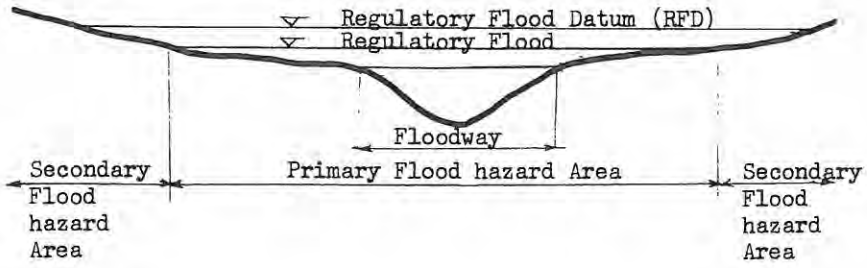
- the possible intensity and duration of rainfall in the area concerned, as well as in adjacent areas

- the topography and morphology of the area concerned
- the ground water level
- the saturation capacity of the soil
- the use of local information

3.2.2 On the basis of the results of the above study, governmental or local authorities should determine the "Regulatory Flood" usually with a small probability of exceeding an occurrence of once every 100 years, expressed as the height of water level above mean sea level (MSL). The Regulatory Flood Datum (RFD) is the Regulatory Flood plus a freeboard factor of safety established for each particular area, which tends to compensate for the many unknown and incalculable factors that could contribute to flood heights greater than the computed Regulatory Flood.

3.2.3 On the basis of the Regulatory Flood Datum a map of the flood hazard area should be drawn up. This map should determine:

- the primary hazard area - the land adjoining the floodway that is covered by flood water during the Regulatory Flood
- the secordary hazard area - the land area beyond the water surface limits of the Regulatory Flood that could be affected by higher floods, underground water travel, and other factors.



6.3 Minimizing of fire risk

6.3.1 The use of fire-proof materials in the construction of buildings is one good way of minimizing fire risk, but this is not always possible for reasons of economy.

Where combustible materials are used, fire protection measures should be stricter, especially as far as the following points are concerned:

- protection against the inflamation of combustible materials (wood, plastic) by impregnation and the use of special coatings
- greater density of fire extinguishing equipment in buildings.

6.3.2 After being exposed for a certain length of time to burning furniture, floors, windows, doors, etc., the load carrying capacity of the structural elements of a building which are made from fire-proof materials (aluminium, reinforced concrete, steel) can be reduced to such an extent that it results in the collapse of the building. The bearing capacity of steel is reduced by the effect of high temperature much more quickly than that of concrete. Thus a steel framework of a building should be given good thermal insulation.

In reinforced concrete structures steel bars in the concrete should be well protected by:

- using good-quality compact concrete, with a low water/cement factor (concrete with a higher water/cement factor is less fire resistant)

3.2.4 Every building (or space) above the RFD may be considered to have a very low risk of flooding

3.2.5 If part of a building is below the RFD, the building can be considered as flood-proof if the floor and walls of the part of the building below the RFD are waterproof.

3.3 Defence System

A special system of flood-protection structures should be developed for the protection of an area from inundation.

3.3.1 Flood-protection systems should consist of:

- a main defence line to ensure the protection of the whole area;
- local defence lines to ensure the protection of various parts of the area if the main defence line is destroyed.

3.3.2 Flood-protection structures of defence lines should consist of:

- dikes (levees) or embankments built to protect the land behind them . A liberal free-bord may be used in the case of poor foundation conditions to cover excessive settlements of the embankment.
- Floodwalls, quays, and embankments built to protect settlements;
- security floodgates and a system of canals for the discharge of floodwater into temporary reservoirs;
- a system of canals, wells and sewerage together with their equipment, which influence the ground water level (water table);

6. FIRE

6.1 Introduction

A fire is not a disaster if it strikes only one building, but it can be disastrous if it spreads over a wide area of a settlement. This may occur when fire accompanies other natural phenomena (earthquake, cyclone, explosion).

During the disastrous earthquake in Tokyo (1923) most people perished because of fire (about 100,000 dead), which spread from the fireplaces in wooden houses, where fires were burning at midday. The mass short-circuiting of electrical wiring and the damaging of gas installations that is caused by earthquakes may also result in disastrous fires. Therefore special attention should be paid to fire protection in earthquake prone areas.

In countries where no legislation and/or no organization for fire protection exists, even an ordinary fire breakout can become a disaster.

6.2 Legislation

Legislation for fire protection should define how the following problems are to be solved:

- minimizing fire risk in every building
- the rescue of inhabitants from buildings in case of fire
- the extinguishing of fires
- the prevention of the spread of fire from one building to another.

- pumping capacity to dispose of drainage water within level system.
- Roads and lines of communication for access to the defence system, to enable the movement of equipment and people during defence operations or for maintenance;
- watchmen's houses, storehouses (for sacks, shovels and tools) and supply depots (of earth and building materials);
- telephone, telegraph and radio communications systems;
- hydrometric and other installations for observing and signalling the approach amd movement of flood waves and ground water level fluctuations;
- structures and buildings of the system which would provide a connection with other hydro-technical systems in the defence area (high dams, dikes, siphons, sluices and pumping stations).

3.3.3 Structural details

3.3.3.1 Dikes

Dikes should be constructed with a section capable of supporting imposed loads and providing the required impermeability. Suitable material should preferably be available at the site and should be tested and approved for use prior to constructing the dike.

At locations where the foundation material has a high degree of permeability, an impervious cut-off may be needed to reduce seepage through in-situ foundation materials. The cut-off may be a sheet pile wall, a compacted barrier of impervious soil or some other similar structure. As no cut-off is totally impermeable, provision should be made

If the coast topography is flat, the protection of structures against tidal waves can be provided by supporting structures on timber piles and poles or concrete piles and columns to provide a sufficient clearnace of the lowest floor of the structure above high water-level.

5. FLOODS RESULTING FROM TSUNAMIS (TIDAL WAVES)

5.1 Introduction

Strong earthquakes may produce sea waves called tsunamis. In deep-sea areas these waves have a long wave length and are therefore practically invisible. On reaching shallower water, however, the wave length becomes shorter and the height correspondingly greater. Tsunamis may strike the coast as very high flood-waves.

5.2 Protection of buildings

Tsunami waves have a destruction potential because of the large and sudden forces exerted on any object situated in their flow path. The duration of immersion is generally much shorter than with river floods.

Buildings and houses in tsunami areas should be built of solid material (brick, concrete) to be able to resist the horizontal drag exerted on them, while submerged.

Precautions for the quick drying of immersed houses are similar to those in the case of inundation.

The protection of settlements on the coast against tsunami by the construction of embankments and flood-walls is very expensive and can be justified economically only in special cases.

The most efficient way of protecting buildings in the tsunami areas is the construction of new settlements, if possible above the locally acceptable risk level.

to collect excess seepage. The seepage can be collected with drainage blankets, pervious trenches, or perforated pipe drains placed at the toe of the embankment and on the dry landward side. Maintenance and seepage control should be ensured.

Drainage should be provided behind the dikes, mainly in inhabited areas, to protect building basements from inundation.

3.3.3.2 Floodwalls

Floodwalls are generally used in tight, restricted areas where foundation conditions are favourable. Usually, protection by flood wall is adopted to make smaller areas containing buildings or settlements close to the floodway flood-proof.

The most common building material used for flood walls is concrete or reinforced concrete.

3.4 Maintenance of the defence system

In non-emergency periods the floodway and the flood defence system should be well maintained. This should include

- the repair of embankments, maintaining normal flow capacity of watercourses by dredging and clearing, and the maintenance of sluices, watergates and other equipment;
- maintenance of hydrometric installations, provision of a daily information service on water-levels in the area subject to inundation, and in adjacent areas which affect the hydrological situation in the protected area;

- maintenance of storehouses for equipment and materials to be used during emergencies;
- taking care that no gaps (e.g. breaks in dikes and embankments) arise in the existing defence system during construction of new roads, bridges, buildings and settlements;
- taking care that the underside elevation of new bridges is at least 50 cm above the RFD; more free space should be provided if rivers flowing through wooded areas can carry off trees during a flood.

3.5 Protection of human settlements

For the protection of human settlements in areas of inundation where existing defence systems cannot provide total security, the following steps should be taken:

3.5.1 The level of roads and tracks should be designed to be as high as is economically justifiable to assure uninterrupted access to settlements and buildings during flooding.

3.5.2 When the water-level in the watercourse is high in an area where the soil is very permeable, inundation can be caused by the raising of the water table. If new settlements or houses are planned in areas subject to inundation and where such soil exists, it is recommended that these sites be raised before construction begins.

3.5.3 In settlements where a sewerage system exists, if the flood water-level is higher than the level of the sewage outfall, sewage will back up in the sewerage pipes and may be discharged into the land causing contamination and outbreaks of disease. This contaminated water can make well water unfit for use for a long period afterwards.

4.3.4 The administrative authority responsible for the dam should maintain a logbook of the dam, including:

- additional construction work on the dam
- all results of measurements
- all phenomena which can be observed visually
- data about high water levels, earthquakes, landslides and other natural phenomena
- results of measurements made during the occurrence of natural phenomena
- control of the alarm system.

4.4 Protection of the population

The destruction of a dam produces two kinds of water wave: a positive wave with downstream propagation and a negative wave with upstream propagation, both decreasing the water level in the reservoir. The positive wave is a danger to the population living in the down-stream area; the negative wave is dangerous mainly for water-borne craft moored upstream.

Modern methods of hydraulic analysis and results of experimental model studies can be used to determine the extent of flooding, and the affected area should be traced on a map.

If high waves menace settlements in this area a plan should be drawn up for the high-speed evacuation of population, taking into account the height of the flood wave and the altitudes of surrounding hills and safe buildings.

The operation of a warning system may ensure timely evacuation of threatened areas.

4.2.2.3 Extensive hydrological investigations should be carried out, with an adequate safety factor against failure, to avoid the destruction of the dam because of insufficient overflow capacity.

4.3 Observation of large dams

4.3.1 Technical observations include inspections, measurements and other investigations concerning the stability of the dam, or of parts of the dam, especially concerning the behaviour of foundations and the stability of reservoir slopes.

4.3.2 Every high dam should have its own portfolio containing:

- the principal data about the dam (plans and technical characteristics)
- the program of the observations to be carried out.

4.3.3 The program of observations should provide the following:

- a description of instruments to be used for observations
- the location of points to be measured
- the kind of measurements to be made (displacements, settling and lifting due to creep, shrinkage, temperature changes etc.)
- a timetable of measurements to be made at the start of construction, during construction, during the first filling of the reservoir, during normal operation and during emptying of the reservoir
- permissible values for each kind of measurement
- the method to be used for examination of the values obtained.

Therefore sewerage systems in areas of inundation should be provided with equipment to close sewerage pipes when inundation occurs.

3.6 Protection of houses and buildings

To avoid serious damage to buildings and houses in an inundated area these recommendations should be observed:

3.6.1 All building materials which lose their strength and load-carrying capacity when immersed in water, such as adobe and clay mortar, should be avoided.

3.6.2 Inundation may give rise to scouring around the foundations of structures. Therefore fine sand deposits should not be used as foundation material in areas of inundation.

Some expansive clays may cause heaving when inundated and consequential displacement of basement floors and possibly foundations. In such cases a layer of gravel should be provided under the foundations and basements.

3.6.3 Seepage of floodwater into buildings whose basements are below the RFD should be prevented.

3.6.4 All openings (windows, doors) in the basement which can be inundated should be provided with display windows (flood shield) and sliding flood shields for doors. These shields should be able to resist the water pressure and ensure impermeability.

3.6.5 If the danger of inundation of the lower floors of a building exists, it is recommended that these floors should be used for activities where equipment could be removed easily (parking etc.). The operating equipment should be installed in the upper floors above the RFD level.

3.6.6 Flooring

In flood areas below the RFD, flooring material which would be damaged by wetting should be avoided:

- water-soluble materials
- materials containing wood or paper products
- impervious materials which are deformed by water.

The following could be considered good flooring materials:

- asphalt
- ceramic tiles
- concrete
- terazzo
- plastic flooring tiles with asphaltic adhesives.

3.6.7 To make feasible the normal use of houses soon after inundation, drying should be carried out as quickly as possible. In the case of wooden flooring, some floor-boards should be fixed only loosely so that they may be easily removed to increase the draught under the floor. Wallpaper and wall-panelling should not be used. Special attention should be paid to under-floor ventilation.

3.6.8 The sewer system in areas of inundation should be provided with one-way (reflux) valves.

4. FLOODS RESULTING FROM THE DESTRUCTION OF LARGE DAMS

4.1 Introduction

The main causes that may lead to the failure of large dams are the rupture of the foundations (40%), insufficient overflow capacity (23%), insufficient bearing capacity of the structure (12%), differential settlement of the foundations (10%), earthquakes, landslides and other causes (15%).

4.2 Design of large dams

4.2.1 Definition

The following dams could be considered as high dams:

- dams higher than 15 m, or
- dams higher than 10 m if the volume of the reservoir is more than 100,000 m^3 or if the flow capacity of the watercourse is greater than 2,000 m^3/sec.

4.2.2 Investigation

4.22.1 Bearing in mind the above causes that may lead to destruction of large dams, it is obvious that special attention must be paid to the investigation of soil conditions as well as to the design of dam foundations.

4.22.2 Recent experience shows that the creation of new large reservoirs can induce earthquakes. In all regions therefore investigations should be carried out to determine the location of seismic faults and seismic loads which the dam must be designed to withstand.