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The Global Blueprints for Change contain guidance for working together to improve the capability to identify indicators of physical, social, enterprise, and environmental vulnerabilities throughout the world and to select and implement realistic solutions to reduce them towards acceptable levels.

Theme B: BUILDING TO WITHSTAND THE DISASTER AGENTS OF NATURAL AND TECHNOLOGICAL HAZARDS
Topic B.7: Improving Vulnerability and Risk Assessment for the Environment

"Measures for Mitigation of Earthquake Impacts"

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MEASURES FOR MITIGATION OF EARTHQUAKE IMPACTS

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Abstract: Human beings have no possibility to avert or to accurately forecast the earthquake, and for that reason they have only a possibility to mitigate its consequences. The mitigation is possible only in the case when we correctly understand to the problems connected with the earthquake impact and when we reasonably assess the present uncertainties. The earthquake impacts may be mitigated by technical, legal, organisational and educational measures. The examples and references used in the present paper are influenced by the fact that author has been living and working in Central Europe and that she has been working for nuclear facilities. (**Note: The full text of paper is prepared in the Czech language (Prochazkova 2001).**

1. Introduction

The strong earthquakes in El Salvador and in Gujaret, India (possibly as many as 50 000 victims) in the year 2001, and those in Turkey on Aug. 17, 1999 and on November 12,1999 (ca 20 000 victims, damages more than 30 billions USD) and in Taiwan on September 21, 1999 (accompanied by the change of terrain morphology) forced us, who work in the professional domain or in the state administration to answer the following basic questions:

- Can such natural disasters occur in our country?
- How is our country protected in the case of impact of strong earthquake?
- Are specialist teams prepared and the means for early and adequate intervention immediately available?

Seismic engineering is a technical discipline that deals with the measures that will reduce the vulnerability of the human society, constructions and equipment to the physical and societal impacts of earthquakes. The contribution incorporates:

- Basic information on earthquakes and their impacts.
- Survey of measures that result to the mitigation of earthquake impacts.
- Survey of seismic engineering problems.
- List of professional literature in which the detail data and knowledge are given.

A Blueprint is designed to promote implementation; therefore, it deals with the requirements from the perspectives of:

- the seismic safety viewpoint, i.e. with the measures that must be done to protect the human lives, property and environment,
- the viewpoint of accessible financial means, because the permanent financial deficit causes that in practice, there are only implemented these measures that are perforce necessary and that are in appropriate quality.

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This pragmatic approach also reflects the experiences obtained during the IDNDR programme. It showed that the advanced countries are only capable to carry out the activities (research, technical standards, legal rules, inspections, sanctions etc.) leading to the setting up the preparedness to the earthquake impact. To the others, i.e. to the lesser developed and developing countries, it is necessary to help by the technology transfer, population education and by finances.

2. Basic Information on Earthquakes and Their Impacts

The earthquake originates by the sudden release of mechanical energy. Each earthquake is necessary to characterise by the geographic co-ordinates of focus, the focal depth, the origin time, the size, the orientation of forces acting in the focus (predominant force multipole), the stress drop as a consequence of failure, the size of irreversible strain of focal region and its time course, the shape of fractured region and its size and by the distribution of earthquake macroseismic impacts on the Earth's surface, constructions and humans.

The earthquakes that are manifestation of tectonic activity, originate under the conditions that vary in dependence on the tectonic zone. These conditions are consequences of long-term tectonical movements, the velocity of which is, in comparison with the human life, i.e. with human observation possibilities, very low. By the comparison of seismic activity with geological structure of the region, there is necessary to consider, that the accuracy of earthquake foci positions are not always the same, and that from the whole process of earthquake origin we have only the data on the part of process in a limited time interval. The period of several centuries from which we have data on earthquakes may be too short for the assessment of dynamics of processes of intensified and diminished earthquake activity.

The earthquakes originate in the lithosphere, i.e. in the Earth's crust and in the upper mantle. The lithosphere (the layer with thickness of 100 - 120 km) consists of blocks and plates reaching up to the size of continents and oceans. As a consequence of running tectonic processes (i.e. the processes running within the Earth's body) the blocks and the plates constantly move. The earthquakes originate by the brittle instability or by rough sliding, mainly on the plate boundaries. The earthquake foci as a rule reach up to the depth of several km up to several tenths of km; on the boundaries of continental and oceanic plates they reach up to the depth of 700 km.

The earthquake foci are not uniformly distributed. They are concentrated to some regions that we call focal provinces. The individual focal provinces we describe by the predominant focal mechanisms, the typical focal depth, the typical isoseismals, typical value of intensity attenuation or by the typical value of seismic energy attenuation, the magnitude-frequency graphs, the Benioff graphs, maximum observed earthquake, typical earthquake sequences and appropriately by the foci migration (Prochazkova 1984, 1990, 1993a). As far as we mention the typical quantity, we understand the mode determined of the frequency distribution of values of quantity.

Apart from the focal provinces there are broad areas (continental shields), on which the sporadic scattered earthquake foci occur. They are not connected with the expressive fault structures of regional sense, but only with the structures of local sense, on which from time to time the limit rock massif strength may be exceeded (Prochazkova, Roth 1993, 1996). With regard to the reality that the local structures are not extensive, they can only accumulate a small amount of energy that correspond to their dimensions. Therefore, the earthquakes on these structures are small. In the sense of the IAEA safety guide (IAEA 50-SG-S1) and the US NRC Regulations (Budnitz 1995) we define them as regions with the diffuse seismicity.

On the existence of local stresses in the "aseismic" regions (i.e. regions in which no earthquake foci occurred during last several hundred years from which we have data) we are assured by earthquakes in Lubin 1977, Gazli 1976, Asuan 1981 etc. that are induced by special human activities. We observed the rockbursts, the earthquakes induced by dams, artificial explosions, injections of liquids into the rock massifs and by withdrawing liquids from the rock massifs (Prochazkova 1993b).

At our considerations we assume that earthquake foci are connected with the origin of fractures or with the block movements along to living (active) tectonic faults. Deep drill holes (Kola peninsula in Russian Federation, Weiden in Germany) show that minimally in the interval of shallow earthquakes (i.e. up to 12 km) does not come to the change of rock massif physical properties, so that the earthquake foci cannot originate without the existence of deep faults.

At the investigation of genetic connections of earthquake foci with the horizontal and vertical fault structures in the medium we do not assume that each fault must be continuously active. We take into account the existence of gaps in time and space. The fault we do not consider as a thin linear dislocation but as the set of fractures roughly parallel that create the fault structure, belt, zone.

From the seismological practice (e.g. Niklova, Karnik 1969) we know that the determination of boundary between two neighbouring regions is difficult. By application of statistical methods based on the determination of inflexion points on the summation curves, constructed for selected azimuths either for the number of shocks or for seismic energy released, there is incorrectly possible to locate the boundary into the place, in which there is now the calm of seismic activity, i.e. gap that will fill in the future by the earthquake occurrence. Therefore, it is reasonable to create focal provinces as seismotectonic units (Prochazkova 1984, 1993).

The tectonic processes under way in the Earth are the main source of the stress cumulating in given places in which after reaching certain critical stress level the earthquakes or landslides or volcanic eruptions occur from time to time (e.g. Prochazkova, Roth 1993, 1996). The most losses are caused by earthquakes because they suddenly come and affect large territories.

The macroseismic impacts of earthquake depend on many factors, namely on the earthquake size, the dimensions and depth of earthquake foci, the distance between epicentre and observation site and on the site ground response. The role also play the fault location in focal province and the properties of medium in which seismic waves propagate. The earthquake impacts at given site depends on the local geological structure; at places no so distant it is possible to find big differences in earthquake macroseismic impacts that are a manifestation of resonance properties of ground. At buildings and their equipment there are manifested physical properties as the capability of resonance, if the prevailing frequency of seismic waves is near to their resonance (natural, eigen, proper) frequency (Drimmel 1980, Prochazkova 1984).

The earthquake enforces the buildings and their equipment into forced oscillations. The size of these oscillations depends on the earthquake size, on the links between the buildings and ground and on the mutual links among individual parts of building. If the building is capable to generate proper oscillations, the ground oscillations with frequencies identical with the eigen frequency of building are risky for the building. The buildings behave as the heterogeneous systems that are consisted of great number of elements the solidity of which varies in broad ranges and changes during the earthquake.

3. Survey of Measures for Mitigation of Earthquake Impacts

Important measure for the reduction of losses caused by earthquakes seems to be the earthquake prediction. The prediction has scientific, economical, legal and sociological aspects. Its physical background is based on the reality that the earthquake as each physical phenomena prepares during given time period. During this time the physical and chemical properties of the medium change. These changes observed as anomalies of parameters we denote as symptoms of forthcoming earthquake. Several thousand professional papers that have been published since the middle of last century (Prochazkova 1989), only show that:

- There is not simply possible to transfer earthquake symptoms from one region to another one.
- Each region under account from the earthquake prediction viewpoint must be comprehensively investigated for a long time because the focal processes in each focal province change with time.

Because there are a lot of uncertainties in data on earthquakes, the earthquake prediction is not reliable at present. With regard to the reality that earthquake is one of natural disaster, which is and for a long time will be unpredictable, the population early warning before the earthquake and the risk technologies apposite shutdown in real time have not been nearly feasible. Therefore, for the mitigation of impacts of possible strong earthquakes to the minimum we perform at regions threatened by stronger earthquakes the preventive measures. The measures are divided into technical, organisational, legal and educational.

- Technical measures, i.e. measures connected with selection of building materials and the suitable method for the construction of civil and technological facilities that assures facility seismic resistance at the earthquake impact up to the given earthquake size. The measures consist in:
    - selection of materials,
    - selection of construction methods,
    - fixture of special protective equipment as insulators, dampers, energy dissipaters etc.,
    - assurance of redundancy of important parts of technological equipment including their layout in space,
    - application of special operation procedures.

  These measures are sometimes technically and financially expensive, and therefore, they must be preceded by the detail study consisting in limitation of focal provinces, determination of focal provinces characteristics and in assessment of seismic wave propagation between the site and the focal provinces. The technical measures are given in norms and technical standards (e.g. Zakon 50/1976 Sb., ASCE 1996, CSN 73 0036, JEAG 4601, KTA 2201.1, SRP 1988).
- Organisational measures, i.e. measures connected with the assurance of preparedness for the earthquake impact and for eventual human evacuation. These measures represent sets of measures for inhabitants, managers and for workers in technological facilities. Civil measures as anchored furniture to wall, extinguishing free fire at earthquake impact,

closure of gas at earthquake impact etc. are simple but very efficient. Their application markedly mitigate the earthquake impacts and ensure preparedness of means and aids for the earthquake consequences remove. The measures of this type are in facility on-site and off-site emergency plans and in city emergency plans.

- Legal measures, i.e. the codification of indispensable technical and organisational measures, because obligatory and thus enforceable there are only those requirements that are confirmed in the legislation. This is really necessary in domains to which the protection against earthquake impact belong, that are not immediately profitable, and even in short-term and medium-term time interval they reduce the profit. The examples are e.g. in (RG 1.70 1978, JEAG 4601).
- Educational measures. Their aim is mainly to avert panic that as a rule is responsible for more human victims than the direct earthquake impacts and to lead the humans to such behaviour that might reduce the secondary earthquake impacts as are fires, leakage of gases and toxic substances etc. Another aim is notification of population, what it is necessary to do before, during and after earthquake. The examples are in textbooks for schools (CO 1999) and in facilities plant operation procedures (Prochazkova 2000).

For the accomplishment of aims the findings of seismology, geology, geomechanics, construction and technology are not sufficient, and therefore, the principles of optimal management must also be taken into account. From the same reason it must be applied the latest findings for the uncertainties of input data assessment, i.e. fuzzy sets, experienced databases, qualification of experts, expert method application.

The vulnerability of human society drastically increases with the increase of number of humans and with the technological development. Each technological complex (dam, nuclear power plant or another critical facility) introduced into the practice corresponds by its level to knowledge status at the time of its design, to financial and technological possibilities of creator, i.e. it has preferences and weaknesses that are amplified or weakened by the site conditions.

From the viewpoint of protection of human population and of environment there is necessary at the design, construction and operation of each facility to solve not only technological questions but also legal questions, education and training the population, namely in the domain of correct and safe operation of facility and in the domain of earthquake impact on facility and its vicinity.

It is generally known that human knowledge and experiences have been developing in time. In the past it was documented by the changes of norms and technical standards that were enforced by the assessment of several past earthquakes, e.g. Loma Prieta 1989, Northridge 1994, Kobe 1995, Turkey 1999, Taiwan 1999 (Prochazkova 2001). The important finding of the last decade it was the refutation of the usual statement that the vertical ground motion acceleration is smaller than horizontal one.

The preparedness for the earthquake impact means that during and after strong earthquake it is averted the origin of:

- panic among people and with it connected unnecessary human victims,
- technological accidents,
- secondary impacts as fires, contamination of environment by chemical and toxic substances, i.e. unnecessary harms of the property and of the environment,
- collapse of buildings with a great number of people,

namely by the way that:

- there are prepared the organisational plans (emergency plans), technical forces and means for help to people in damage areas and for the liquidation of damages caused by earthquake,
- workers of the technological plants and inhabitants know how protect themselves, colleagues and relatives at the earthquake impact, and they know the instructions of plant management and of local authorities for the case of earthquake impact (i.e. the relevant part of the on-site and off-site emergency plans and of city emergency plans).

In the first it is true that the prevention and preparedness begin with information, because both items mentioned depend on the site conditions and on the earthquake impact scenario. The scenario is defined by both, the earthquake size and the site properties that pre-determine the origination and size of some attendant phenomena. Therefore, in each locality we must know the vulnerabilities of individual buildings and plants (civil and technological facilities) and their equipment and also possible scenaria of earthquake impact on those structures in dependence on local ground conditions. It is necessary to know the number and distribution of people in locality and their probable behaviour at the earthquake impact.

It means that for the preparedness assurance it is necessary to know the seismic hazard of locality related to the relevant time interval and the seismic risks of individual structures (the seismic risk is a combination of seismic hazard and the vulnerability of structure and vulnerability of its ground). For the locality seismic hazard assessment and consecutively the seismic risk assessments we must know the geological, tectonical, seismological and geomechanical characteristics of locality. For the seismic risk assessment also the structures, systems and components of civil or technological facilities and their govern links must be known.

With regard to the demands mentioned above, the preparedness for the earthquake impact is not only the matter of individuals but it is a matter of society, i.e. of the state authority and it belongs under its management. From the methodological viewpoint there are important the methods of decision-making and of management. To ensure that damages and human losses ought to be minimal and that expenses on the realisation of system of preparedness for earthquake impact ought to be acceptable, there must be applied the relevant methods of decision-making and of management that ensure that:

- all relevant data are taken into account including all uncertainties,
- for the results interpretation there are used validated procedures.

It means that for the management of defence against earthquake impact, the individual decision-makings in all stages (before, during and after earthquake) must start from the diagnose of significant items of earthquake impact scenario and its hierarchy, and from the objectively relevant and as optimal as possible strategy of scenario of actions for the earthquake impact mitigation. In this context the content of term „the optimal strategy“ is determined by the philosophy of „rescue“ (notes: the strategies of rescue and of attack differ in the different order of aims; against earthquake we cannot fight with the aim to beat it but with aim to protect ourselves). From the theory of tactic it follows that for the reduction of losses it is important to start the counter actions in relevant order. The experiences show that in practice it is from time to time impossible to start with the most effective actions, because in the moment of decision-making it comes into existence the rescue of one real human life (e.g. child) that is in contradiction with measures of the most effective action, i.e. the ethic problem arises. From the human and ethical viewpoint both problems must be solved during the rescue action.

For the rational decision-making the real problem, the following procedure must be introduced (Prochazkova 1996):

- collection and processing data,
- recognition of possible variants of solution the problem,
- statement of optimal solution,
- decision-making.

4. Procedures Used in Practice

There are many procedures that are used in the seismic engineering domain with the aim to mitigate the earthquake impacts. In this paper we concentrate to the basic ones as:

- focal provinces determination,
- maximum possible earthquake determination,
- seismic hazard assessment,
- seismic risk assessment,
- seismic terms of references,
- seismic risk management,
- seismic inspections.

4.1. Focal Provinces Determination

The earthquake foci mostly concentrate to regions that we called “focal provinces”. For their delimitation simple or more complicated methods are used. The simple methods are based on the judgement (assessment) of expert who usually with regard to safety reasons a little enlarge the data followed from observations. The more complicated methods are based either on the aggregation of assessments performed by several experts, who step by step assess the tectonic and seismic activities and their links, taking into account themselves knowledge and experiences (Budnitz 1995), or on the assessment of selected symptoms of tectonic and seismic activities according to defined methodology.

The reliable determination of focal provinces must be performed on the basis of seismological, geological, tectonical and geodetical data. Only the synthesis of knowledge from the different branches can reduce the uncertainties that are objectively caused by the input data indefiniteness that are not random character, and therefore, they cannot be removed by the statistical data processing.

In agreement with Grin and Knauf (1978) we define the boundaries of focal provinces by the way, that they separate the regions with the different space - time dependencies that are valid for the earthquake occurrence. In the case of greater depth capacity we divided the focal provinces into several floors (layers) that we separately investigate, because the characteristics of seismic activity depend on the depth (Prochazkova 1984, 1993).

At delimitation of focal provinces we pass from the small clumps of foci that are as a rule connected with the movements along to one fault or along to the system of several parallel faults. We take into account the reality that the earthquake foci, mainly those stronger are situated on the fault crossings because these places create the weakest parts of region that is under the action of tectonic forces.

The greater focal provinces we create on the basis of similarity of quantitative and qualitative seismic characteristics of individual small focal provinces (Prochazkova 1990), because we consider the assumption that partial focal provinces create the seismotectonic units, only when they are characterised by the same process of earthquake origin and by the same geological, tectonical and geomechanical properties.

The boundary of focal provinces we define as a boundary that surrounds (Bune, Vvedenskaja, Gzovskij 1968, Budnitz 1995, Hays 1980, Gelfand et al. 1972):

- all known earthquake foci occurring in the historical time and in the case when there are the reliable evidence on pre-historical foci from the research of paleoseismicity, so the boundary also includes those,
- the region in which the earthquakes with the same characteristics of seismic regime occur,
- the region with the same geological, tectonical and recent movements characteristics (Prochazkova, Dudek 1982, Prochazkova, Roth 1993).

4.2. Maximum Possible Earthquake Determination

For the determination of maximum possible earthquake in a focal province there are used the methods based on:

- sum of size of maximum observed earthquake in the historical time and 1° MSK-64 (Kijko, Sellevoll 1988, Prochazkova et al. 1990, RSF, Jalil 1992),
- extrapolation of oscillations of the Benioff`s graph (Bath 1981),
- curvature of magnitude – frequency graph in the range of strong earthquakes (Mirzojev 1976),
- correlation of maximum observed earthquake with a seismic activity defined for the selected level of earthquake activity (Riznichenko 1962),
- theory of extreme values (Epstein, Lomnitz 1966, Gumbel 1954, Schenkova, Karnik 1974, Kijko, Sellevoll 1988),
- correlation of maximum earthquake size with a fault length (Ramelli, Slemmons 1990),
- geodynamic factors (Gelfand et al. 1972, Borisov, Reisner, Sholpo 1975, de Polo, Slemmons 1990).

Above mentioned methodologies do not give as a rule same value. The values are inaccurate because there is a lot of uncertainties in data. Therefore, seismic engineering for important (critical) facilities uses the more complicated methods, based on processing the different data sets. We use expert assessment, geological assessment, statistical assessment and geological-statistical assessment.

- Expert assessment. It is based on the summation and evaluation of opinions of several seismologists on the seismic activity of individual tectonic zones and on the size of maximum possible earthquake that real geological unit is capable to generate. In the case of equally documented different alternatives of maximum possible earthquake size the result is either the most conservative alternative that guarantee the highest safety degree in the case of deterministic approach application or alternative median or median + σ (σ is standard deviation) in the case of probabilistic approach application.

- Geological assessment. It represents the empirical method that on the basis of details on geological structure, tectonic movements in the neotectonic era and on historical earthquakes determines the maximum possible earthquake size in known and potential (determined by geological criteria) focal provinces (Borisov, Reisner, Sholpo 1975, Prochazkova, Simunek 1998). Both approaches deterministic and probabilistic can be applied.
- Statistical assessment. It represents the application of mathematical models (Cornell 1968, McGuire 1976, Schenkova, Schenk 1983, Gibowicz, Kijko 1984, Kijko 1985, Bender, Parkins 1987). Both approaches deterministic and probabilistic can be applied.
- Geological-statistical assessment. It represents the application of mathematical models (McGuire 1978, Johnston, Nava 1990), that also include, in addition to seismological data, the contributions of individual geological and tectonical factors of focal province to the size of maximum possible earthquake. Because the problem investigated is too complicated, the results are up to now too hypothetical. The unknown parameters are e.g. determination of length of seismoactive fault part, the relation between the length of seismoactive fault part and the maximum possible earthquake size. From the factual viewpoint it is possible to expect that these methods will be reliable because they consider the complex information on the region investigated. The progress shows the use of logic tree methodology based on data dealing with earthquakes, tectonic movements and their links with earthquakes in the neotectonic era (Coppersmith, Youngs 1990). The application of logic tree allows to use for the evaluation of different expert's opinions or different seismic hazard values derived by different methodologies the suitable expert's methods (Cerny, Glückaufova, Toms 1980) with the aim to find "the best estimations" (Prochazkova 1993c).

4.3. Seismic Hazard Assessment

The seismic hazard of a site or locality is the size of earthquake (expressed by the earthquake intensity or by peak ground acceleration of seismic waves – PGA) that may be expected at given locality in a specified time interval with a stipulated probability, usually 0.95.

We assume that the origin of earthquakes is a steady uniform process going on in space and time (i.e. in this moment we do not consider the influences leading to the change of processes within the Earth as a consequence of internal and external forces or even by human interventions). Therefore, the seismic hazard at present interpretation is a function of time and space, that means that its value depends on:

- actual position of locality towards focal provinces, the earthquakes of which can manifest by macroseismic impacts here, i.e. it depends on the maximum possible earthquake size in individual focal provinces, on the parameters of medium between the focal provinces and locality in which the seismic waves propagate, and on the distances between locality and focal provinces considered,
- time interval for which the seismic hazard is determined. Because the strong earthquake occurrence frequency is low, the value of seismic hazard is various for different time intervals, it increases with the increase of time interval length.

4.3.1. Data for Seismic Hazard Assessment

Because no guaranty that the known seismic data make up the representative set for the seismic regime characterisation and because the seismic regime is variable in time and space, for the seismic hazard determination the seismological data are not sufficient. According to present knowledge the seismic hazard must be determined by the seismological, tectonical, geological, hydrological and geomechanical data because these data pre-determine the sizes of focal provinces, the values of maximum possible earthquakes in focal provinces, parameters of medium in which seismic waves propagate and also the conditions for origination of local intensity anomalies.

Earthquake macroseismic manifestations in each locality are caused by two categories of earthquakes, namely by:

- earthquakes the foci of which are on the locality territory or in its close vicinity,
- stronger shocks of surrounding focal provinces.

It is necessary to note that earthquakes of both mentioned categories have not the same dynamic characteristics and the same earthquake impact characteristics.

From above reasons, in the practice there must be investigated the focal provinces up to the distance of 200 – 400 km from the given locality. For more distant earthquake we consider, taking into account the research results for Central Europe (Prochazkova 1984, 1990, 1993a), that with regard to global decrease of size of earthquake impacts with distance, more distant strong earthquakes cannot manifest at given place by significative contribution to the seismic hazard.

Taking into account the analyses for nuclear facilities that resulted to the IAEA safety guide (IAEA, 50-SG-S1), we know that for relevant assessment of locality seismic hazard it must be taken into account:

- the regional, vicinity and local characteristics from the viewpoint of seismology, tectonic and geology,
- vicinity and local characteristics from the viewpoint of hydrology,
- local and site characteristics from the viewpoint of geomechanics.

Under the term "regional characteristics" we understand the characteristics for the territory limited by circle with the centre in the investigated site and with radius of 200-400 km and for the time interval of 1 Ma up to tenths of Ma. Under the term "vicinity characteristics" we understand the characteristics for the territory limited by circle with the centre in the investigated site and with radius of 25 km and for the time interval of 1 Ma. Under the term "local characteristics" we understand the characteristics for the territory limited by circle with the centre in the investigated site and with radius of 5 km and for the time interval of 100 000 years. Under the term "site characteristics" we understand the characteristics for the territory limited by circle with the centre in the investigated site and with radius of 0.5 km and for the time interval of 10 000 years. The illustration for site in Central Europe is in (Prochazkova 2000).

Taking into account the safety guide (IAEA 50-SG-S1) for nuclear facilities there are necessary data on:

- geological structure in horizontal and vertical planes,
- structural and fault interfaces,
- tectonic development (chronology of tectonic movements),
- seismoactive parts of faults and on properties of movements generating the earthquakes,

- focal provinces,
- hydrological regime,
- set of earthquakes and phenomena related to them,
- S wave velocity, composition of the upper parts of the Earth's crust, landslides, ground liquefaction and on seismogenerating technological interventions.

These data must be complex (i.e. in addition to values the existing links among data must be given), relevant, validated and documented by quotations of professional works, investigations and tests.

The determination of seismic hazard (RSM 1973, IAEA 50-SG-S1, Hays 1980 etc.) requires the detailed investigated and technical study, that integrate the geological, geodetical, seismological and geotechnical knowledge in regional and local scales. The regional data processing consists in the following steps:

- to make up the earthquake catalogue and isoseismal maps from the historical times up to present, including the analysis of the process of strong earthquakes occurrence,
- to perform the neotectonic studies with the aim to obtain the information on the earthquake frequency in last thousands years that are not documented by seismological observations,
- to perform the seismotectonic map indicating the position of active faults and seismogenic structures and their correlation with earthquake foci,
- to determine focal provinces, maximum possible earthquake magnitude in each focal province and the model of earthquake magnitude-frequency distribution in each focal province,
- to calculate the regional dependencies expressing the attenuation of earthquake intensity with distance in the azimuth "focal province – given locality",
- to compute the seismic hazard by the relevant model (see next paragraph), e.g. for Central Europe it is suitable model (Kijko, Sellewoll 1988).

The local data processing consists of the same steps as are used for the regional data, it summarises and interprets the local peculiarities of territory, it takes into account the local geological structure and its impacts on the ground response at earthquake impact.

Above given demands are of course necessary for all seismic hazard assessments. Because it is financially, timely and technically exigent to collect these data, so at the case of structures that are not so important from the viewpoint of social (political) hierarchy, it is practically impossible to enforce the collection of these detailed data. In this case the determination of seismic hazard is performed either by using the relevant standards, that are based on general characteristics, or by consideration of data summarised in the professional literature, or by consideration of data from professional literature that are verified and completed by data of specialised investigations and surveys. On the basis of author's experiences the use of data from professional literature without verification has pitfalls. In the professional literature there are works based on different hypotheses that are more or less documented by facts, and therefore, they can lead to diametrically different results. It is understandable that in the practice it is necessary to use the scientific hypotheses that are sufficiently documented by facts. Therefore, it is necessary (it might be codified in standards) before the hypothesis application to verify the given hypothesis assumptions and the agreement of hypothesis with the relevant site facts.

Standard procedure for the actual site seismic hazard assessment (for return periods 100 and 1000 years), that is used for current civil and technological facilities, is mainly based on seismological data and consists of the following steps:

- determination of focal provinces, the earthquakes of which can affect the given site by macroseismic impacts. It is necessary to distinguish the seismotectonic zones and zones with diffuse seismic activity, i.e. regions in which it is not clear link between earthquake foci and surface tectonic elements (its seismic potential is assessed on the basis of historical data taking into account facts of similar regions for which long-term observations are to disposal),
- determination of size of maximum possible earthquake that can origin in each focal province of the region under account in a given time interval,
- determination of attenuation curves for the azimuth “site – focal province” for focal provinces of the region under account. From the viewpoint of extreme safety demands it is assumed that in all case the maximum possible earthquake can origin at a place of focal province that is the nearest one to the site, and that curves that correspond to the most unfavourable decrease of intensities with a distance are valid,
- the aggregation of results taking into account all focal provinces, i.e. the determination of maximum earthquake impact on real site and probability of maximum earthquake impact occurrence in given time interval.

4.3.2. Techniques for Seismic Hazard Assessment

The basic data on earthquake impacts may be processed by different ways, and therefore, several levels of seismic hazard assessment exist in practice. The simplest estimation is based on the database of macroseismic data and on the isoseismal maps database (Prochazkova, Karnik 1978). The next simple estimation is the estimation based on the maximum observed intensity map (Prochazkova 1984). The following is the seismic zoning map (Karnik et al. 1988) use in technical standards (CSN 73 0036). These estimations are based on the tacit assumption that the maximum earthquakes occurred in all focal provinces during the observed time period. Uncertainty of such assessment is affected by the validity of mentioned assumption. Sometimes in these connections we say that the seismic safety has a historical limitation. It means that the higher time interval of earthquake observation is, the greater probability, that values will not be exceeded, is.

With regard to the extreme safety requirements for technological and selected civil facilities and to the knowledge that seismic hazard is affected by a series of quantitative and qualitative factors (Krinitzsky, Slemons 1990) above mentioned estimations are not used in the case of critical facilities. The more complicated methods are used.

At the seismic hazard assessment we meet with uncertainties related to random nature of earthquake occurrence and related to indeterminatenesses in the earthquake process. By the application of statistical methods we treat the uncertainties of random nature. The remove uncertainties connected with indeterminatesses in seismoactive structures boundaries, focal provinces boundaries, knowledge of geometrical parameters of earthquake foci, specification of seismic activity, attenuation curves selection, stochastic model for earthquake occurrence, relationships used for computation of magnitudes from intensities and for acceleration values determination, is complicated. In practice for the evaluation of just mentioned type of uncertainties two approaches are used, namely deterministic and probabilistic.

The comparison of values of site seismic hazard determined by deterministic and probabilistic approaches applied on the consistent data set is, e.g. in work (Prochazkova 2000). It shows that value obtained by probabilistic approach is not so conservative as value obtained by deterministic approach.

For determination of seismic hazard value there are used the statistical models (algorithms), e.g. (Cornell 1968, Bender, Parkins 1987, Kijko 1985). Kijko derived the model suitable for Central Europe. At the theoretical model application there is assumed that:

- observed seismic activity trend will be preserved in the future,
- homogeneous distribution of earthquake foci exists in the each zone,
- random occurrence of earthquakes in space and time exists,
- independence in the earthquake occurrence in individual focal provinces exists,
- same attenuation exists in the region under account.

The hazard curves are calculated for the annual probabilities of non-exceedance of 0.95, 0.85, mean, median and 0.05 in the dependence on local geological conditions.

At the given calculations (substitution of numerical data into theoretical models) it is necessary to take into account that the results do not only depend on the data set that is used for actual region but also on the model calibration that is pre-determined by the determination of maximum possible earthquake value and by the determination of focal provinces boundaries. At the computation we consider that the earthquake can origin in any point of each focal province and everywhere it can reach the maximum possible earthquake value.

4.3.2.1. Deterministic Approach

This approach consists in the special evaluation of indeterminatesses of all input parameters. Owing to seismic safety demands they are considered the most unfavourable values and in practice two basic procedures are used:

- Statistical. It is based on the evaluation and procession of historical earthquakes in the region under account. It is assumed that earthquake foci concentrate in focal provinces. The procedure consists of four steps:
    - identification of focal provinces and determination of maximum possible earthquakes that may be generated by these provinces. The most unfavourable data with regard to site are used,
    - determination of magnitude-frequency relations for each focal province and for the region under account. The most unfavourable data with regard to site are used,
    - determination of model describing expected change of parameter that characterises the ground motion (intensity, acceleration) as the function of magnitude and distance of site from earthquake foci. The most unfavourable data with regard to site are used,
    - synthesis of data for all focal provinces and the computation of the hazard curve for selected time intervals. The most unfavourable data with regard to site are used.
- Tectonical (in literature the term „seismotectonic“ is also used). It is based on the use of geological and tectonical assumptions that pre-determinate possible generation of earthquakes by faults. The procedure consists of two steps:

- evaluation of tectonic, geological and seismological data. There are summarised and evaluated opinions of the prominent seismologists and geologists on regional tectonic mobility, determination of active tectonic structures (i.e. tectonic structures with capability to move), determination of seismogenic tectonic structures and on determination of their activity including the size of maximum possible earthquake that may be generated by the real structure. The method for real data assessment was processed in several procedures (Borisov, Reisner, Sholpo 1975, Alen 1986, Slemmons, de Polo 1986, Prochazkova, Simunek 1998, Krinitzsky, Slemmons 1990). All procedures have the common feature, i.e. the evaluation interdisciplinary data set that are related to the seismogeneration of region. The most unfavourable data with regard to site are used,
- determination of seismic hazard value. The most unfavourable data with regard to site are used.

4.3.2.2. Probabilistic Approach

For the evaluation of phenomena and processes the characteristics of which are not clearly deterministic, i.e. they have uncertainties of different nature there have been used since 80s so called expert methods (Cerny, Glückaufova, Toms 1980, Kotek, Marik 1982, Levine, Drang Edelson 1990, Marik, Zdrahal 1982, 1984, 1985, 1987, 1989), that are based on the aggregation of results that either were produced by the expert group or created by different way determined input data.

From the mathematical statistics and of theory of fuzzy sets (Zadeh 1965, Riha 1995) it follows that uncertainties of random nature are possible to eliminate by the statistical processing, and the rest uncertainties is possible to assess by use of experts with different experience, with different view on the problem and by application of experience (empirical) databases.

In practice for the determination of seismic hazard value by probabilistic method there are use the same methods and algorithms as for deterministic approach (see par. 4.3.2.1). The difference consists in the fact that in procedures and algorithms there are not substituted the most unfavourable values by individual parameters, but the values corresponding to individual variants of process of the highest earthquake impact occurrence in given locality. The final value is obtained by the aggregation of values obtained by the individual variants that must be defined by the pre-described way.

It means that on the analysis of real case, there are determined variants of earthquake impact occurrence at given site (locality) by the way that variants reflect stipulated uncertainties in boundaries of focal provinces, seismic regime of focal provinces, the b parameter of the magnitude-frequency relation, size of maximum possible earthquake, level of data homogeneity and in attenuation between focal province and given site. For each variant the seismic hazard value is determined by selected method.

It is rational to require that variants of earthquake impact occurrence might be realistic. The author’s experiences of review processes show that without a deep knowledge of algorithm of real „often denoted as the most perfect“ software it is not possible to apply this software on the creation of sets of variants because some of them have not accreditation and they have logic errors, e.g. some variants repeat (they were selected in different order of parameters with uncertainties) and some of them describe unrealistic situations that were created by mechanical selection of combinations.

The aggregation of results of assessments of variants by stipulated way means the statement of representative value of seismic hazard on the basis of values computed for individual variants. In practice there is used for aggregation the method based on median or on median + σ (σ - standard deviation).

4.4. Seismic Risk Assessment

The seismic risk is related to given site, facility, construction or equipment. It presents a set of phenomena that take place at impact of earthquake with size and characterisation corresponding to seismic hazard on the confidence level of 0.95 in given time interval. It depends on the seismic hazard of locality and on the seismic vulnerability of site, facility, individual constructions and their equipment at the earthquake impact.

The basic requirement of human society is that seismic risk must be acceptable, that is determined by legal rules. It is also true that the seismic risk acceptance changes in time, that is valid for any risk, e.g. consider the change of nuclear power plants acceptance after accidents in Three Mile Island and in Chernobyl. Quantitatively, the acceptable seismic risk means the set of phenomena that are tolerable at the earthquake impact.

Seismic vulnerability of construction follows from earthquake size and earthquake ground motion characteristics (maximum amplitude of acceleration, maximum ground motion duration, design spectrum). Taking into account the construction characteristics we can determine with a given probability places in which can occur damages of defined extent at earthquake impact.

In practice the seismic risk is determined on the basis of assessment of response of constructions, systems and components of facility to earthquake with defined parameters. For its assessment in case it is necessary in each case:

- to create the tree of faults and events that lead to accident of critical facility or of its most vulnerable and most risk technological part, i.e. they lead to defect or to loose of functional capability of relevant components,
- to determine the probability of occurrence of individual scenario leading to technological accident .

For designer the seismic risk is defined by the response spectra form and by ground strong motion duration or by accelerogram set.

4.4.1. Data for Seismic Risk Assessment

Above mentioned definition states that earthquake risk is connected with real structure (site, facility, construction, equipment). Therefore, for seismic risk assessment we need data on the seismic hazard of locality and data on site ground, facility structure etc., that are related to their response to seismic waves.

Seismic input data that we need for the seismic risk assessment are:

Safe shutdown earthquake (SSE) - the greatest earthquake, defined as an extreme natural event of this type, that may potentially occur at the site. In conformity to the IAEA safety guide (IAEA 50-SG-S1) it is required that its minimum value for nuclear installations should be chosen as 0.1 g (it is denoted as SL-2). This earthquake that is based upon an evaluation of the maximum earthquake potential considering the regional and local geology and seismology and specific characteristics of local subsurface material. Safe shutdown earthquake is that earthquake that produces the maximum vibrator ground motion for which certain structures, systems and components are designed to remain functional.

Design basis earthquake (DBE) - greatest earthquake, defined as a standard external event, whose occurrence may reasonably be expected at the locality of the given nuclear power plant in the course of its technical service life. In the IAEA safety guide (IAEA 50-SG-S1) it is denoted by symbol SL-1. The earthquake considering the regional and local geology and seismology and specific characteristics of local subsurface material that could reasonably be expected to affect the plant site during the operating life of the plant. Design basis earthquake is the earthquake which produces the vibrator ground motion for which those features of the nuclear installation necessary for continued operation without undue risk to the health and safety of the public are designed to remain functional.

Ground motion accelerogram - accelerogram representing the time dependent acceleration at the building bedrock or at ground level.

Duration of maximum phase of acceleration - determined from the real accelerograms. If necessary the far-field and near-field conditions are distinguished.

Floor accelerogram - accelerogram representing the time dependent acceleration of a selected point on the floor.

Ground response spectrum - response spectrum designed for the given free field accelerogram, or for the accelerogram at ground level.

Floor response spectrum - response spectrum designed for the given floor accelerogram.

Each facility (technological or civil), the seismic risk of which we asses, represents the system consisted of elements (components) and links among them. There is possible to subdivide a set of sub-systems (at some level autonomous), that are created either by nature or by human kind and that are mutually affected. They have basic characteristics, properties and different mechanisms that affect possible development scenario of construction response to seismic waves at the earthquake impact.

At systems constituted by humans it is put emphasis on the long service life and on the functional reliability of parts and complex. With time the more and more emphasis is put on the safety, it is the effort to use components and to set up links in order that the occurrence of harmful phenomena at the earthquake impact might be limited to the acceptable level. Each of this sub-system has been only known to some level of details, i.e. in its description there are uncertainties of different nature. The uncertainties are occur in the determination of:

- expected normal behaviour of elements and systems (they are influenced by material properties, manipulations, ageing etc.),
- real behaviour and real states including the distribution and interactions of deviations of parameters caused during the manufacture and operation,
- range of possible variations of basic function of considered system (to the combination of mounting and operating changes and affects of human factor and environment, namely including cases with rare occurrence).

The assessment of safety of technological facilities to which belong nuclear installations, chemical facility, storage of hazardous and toxic substances, military facilities of different types etc., is the basic requirement from the viewpoint of assurance of safety of population and environment. Its aims and principles are codified in legal rules, technical norms and standards. Proper assessment of each facility, its individual systems and components is possible to carry out either by estimation (engineering judgement) on the basis of data of norms and of experience databases, or by mathematical algorithms based either on deterministic or on probabilistic approach.

4.4.2. Methods Used for Seismic Risk Assessment

For the facility seismic response assessment there are used methods based on deterministic approach or on probabilistic approach. In practice there are more and more used seismic probabilistic safety assessment (seismic PSA) and seismic margin assessment (SMA) as described in (TECDOC-724, Hofmayer 1997, US NRC 1980, Kennedy 1996, 1999, NUREG/CR-2300, NUREG/CR-2815, NUREG/CR-4659, Budnitz 1999, Budnitz et al. 1997).

Determination of seismic risk of individual facility or its construction or its equipment is performed either directly (computation, test in laboratory) or indirectly (by analogy). At constructions and their equipment it is necessary to consider the quality and physical properties of materials, ways and quality of mounting and the effects of ageing on material and mounting the structures.

<u>Engineering assessment</u>

It is based on the knowledge and experience of expert who by site walkdown determines if the seismic risk is greater than acceptable or tolerable. The instrument for this type of assessment are norms and technical standards. In recent years there are used experience databases to this purpose, e.g. for nuclear installations the GIP expert system (Masopust 1998). The GIP is expert system for indirect verification of seismic resistance of components of technological equipment (machinery, electric, I & C equipment) that is based on the SQUG (seismic resistance) database, that contents data on seismic resistance of the machinery, electric and I & C components that are sorted according to models, types and producers.

<u>Deterministic method for seismic risk assessment</u>

Deterministic assessment of safety of equipment (or selected systems and components) is codified in legal rules of many countries. It is usually very conservative, because it is based on the most unfavourable estimations of input data and on their most unfavourable combinations that lead to or can lead to defect of equipment. Therefore, it represents the most unfavourable case, namely without considering the reality of this scenario. It consists of two steps:

- determination of the most unfavourable values of input parameters and their most unfavourable combinations, that are connected with the limit earthquake impact,
- assessment of origination of defect of equipment, its individual systems or individual components at the occurrence of the most unfavourable combination of input data by application of statistical methods (there are used frequency distribution of defects and fragility curves).

During the design process the seismic safety is ensured by respecting norms and technical standards and by selection of suitable technological measures.

<u>Probabilistic method for seismic risk assessment</u>

The probabilistic assessment consists of two steps.

- determination of possible variants of behaviour of components and systems at the earthquake impact having the size corresponding to site seismic hazard, and determination of probabilistic curves for occurrence of defects of facility, i.e. its constructions, systems and components that are safety related,

- aggregation of results obtained for individual variants.

Aggregation is performed by two ways. The first one is based on the aggregation of results obtained from several selected experts (their selection is performed according the stated criteria) and is routine in the USA (Coppersmith, Youngs 1990, Budnitz et al. 1997). The other is based on the creation of set of variants respecting possible values of input data and on the aggregation of their results by the method based on median or median + σ.

4.5. Seismic Terms of References

The first part of seismic terms of references for each facility comprise:

- Earth's crust velocity model (its influence is clear in the far field with regard to earthquake focus),
- focal mechanisms (its influence is clear in the near field with regard to earthquake focus),
- source function describing the physical process at the earthquake focus in time,
- focal depth,
- composition of upper parts of foundation under the site.

These data represent the physical characteristics that express facts that seismic waves and their spectra depend on the azimuth between site and fault (influence of earthquake mechanisms), geological structure in the focal region and under the site and on the properties of medium in which seismic waves propagate. They also show the difference between local and near earthquakes that are important for practical definition of seismic input data such as maximum ground motion duration.

In design process it must be taken into account that high-rise buildings shake at relatively distant earthquakes (200 – 900 km), when its resonance period is equal to prevailing period of seismic waves, i.e. 0.5 – 2s, 0.5 – 2 Hz (Prochazkova 1984).

From the computation reasons the influence of local geological structure is also considered in the frequency domain, i.e. the seismic loading spectra are modified by so called transmission medium function. According to the ASCE standard (ASCE 1986) it is not necessary to consider the influence of local geological structure of ground if the ground is created by rock in which the S wave velocity is greater than 1100 m/s.

It is necessary to note that the broadly used assumption that the vertical component of acceleration is equal to two thirds of horizontal component is not valid as shown earthquakes at Northridge in 1994 and in Kobe 1995 (Prochazkova 1995). This fact is taken into account in the safety guide (IAEA 50-SG-S1) revision being under way (OECD 2001).

Designers use the response spectra (i.e. they do not used the seismic loading spectra). The seismic response is a transfer function that characterises the behaviour of facility at seismic loading in dependence on frequency taking into account different damping values and possible modification by site local geological structure, and in dependence on position, i.e. ground and different floors.

There can be used either standard response spectra (RG 1.60, NUREG/CR-0098, Atomenergoprojekt 1977, 1986, CSN 73 0036 – 1990) or site response spectra. The author's experience is that in design phase the use of standard response spectra, that are broad band, is better because possible error caused by not so correct seismic hazard assessment is reduced. The site response spectra are usually use for check of seismic resistance of operating facilities (IAEA 50-SG-D15, Budnitz 1999, US NRC 1980). According to the IAEA safety guide (50-SG-S1) for generation of response spectra three methods can be used:

- standard response spectra,
- specific site response spectra,
- reliable computed response spectra.

Seismic construction and equipment responses depend on PGA, ground motion duration and on the prevailing period of ground motion acceleration at site. In cases when resonance properties of upper parts of Earth's crust, buildings and equipment take place, so specially strong earthquake impacts occur. Therefore, the Japan legislation (JEAG 4601-1987) requires, in order that the eigen frequencies of structures, equipment and foundation levels were different. From the same reason at dynamic computations both, response spectra and accelerograms must use (IAEA, 50-SG-D15).

For the determination of seismic behaviour of constructions and their equipment the PGA is not enough, it is necessary to know accelerograms, response spectra and the response of local geological foundation because each facility is a set of constructions and equipment having different eigen frequencies, and therefore, they are sensitive to different frequencies of falling down seismic waves. Resonance, i.e. the highest effect occur in the case when eigen frequencies of constructions or equipment agree with a prevailing frequency of falling seismic waves.

At design process of civil and technological facilities in practice it is firstly determined site seismic hazard on several levels that correspond to extrapolation for different time intervals. The level of safe shutdown earthquake it is a long-term forecast of maximum earthquake impacts in locality (e.g. for the first seismic category parts of nuclear power plants the hazard assessment for 10 000 years are enough, for the final storage of high radioactive waste it is necessary to consider the assessments for 100 000 years).

It follows the definition of three components ground response spectra, site three component accelerograms, maximum ground motion duration and frequency ground response characteristics if necessary (see ASCE 1986). These values are used for the determination of floor response spectra and floor accelerograms taking into account suitable model of construction of technological facility or it parts. By help of these data there are determined the equipment response spectra for selected equipment that are used in design or in safety analyses.

The next requirement of seismic terms of reference is determination of:

- parameters of seismic instrumentation that must be installed in nuclear power plants (it usually works in trigger regime and its signals are on the desk of the nuclear power plant control room) according to demands (IAEA 50-SG-D15), dam embankments, bridge piles, important high-rise buildings etc.,
- organisational and technical regimes for the case of earthquake impact (criteria of shutdown of technological facility as a consequence of earthquake impact, criteria of start up of technological facility shut down as a consequence of earthquake impact, principles for inspection of technological facility after earthquake impact).

The assessment and explanation of all impacts on facility and on design must be based on one common set of documents. The documentation of respecting design criteria is created by partial assessments and their syntheses. For the answer of several special questions there is performed partial aimed complementation of data, survey works and special investigations (inspections).

Seismic terms of references for the design of nuclear facilities in the Czech Republic (Prochazkova 2000) depend on site seismic parameters and on a facility and type. They are created by the following data:

- safe shutdown earthquake,
- design basis earthquake,
- control earthquake,
- set of ground motion accelerograms,
- set of floor accelerograms,
- duration of maximum phase of accelerogram,
- ground response spectrum,
- floor response spectrum (at least for important floors),
- bounding spectra for important equipment,
- number of earthquakes to be accounted for in the design,
- ranking the nuclear installation constructions, systems and components into seismic categories.

With this seismic terms of references are connected following instructions:

- constructions, systems and components must be designed in order that they might withstand 1 safe shutdown earthquake and a specified number (3-5) of design earthquakes,
- buildings are not designed for fatigue due to design earthquakes. This effect is important for mechanical components at high temperature, and also for sliding devices which are not self-centring, or for viscous dampers, for which cycling may cause considerable temperature increase of the inner fluid.

4.6. Seismic Risk Management

Because we are not able to remove seismic risk (as holds for any risk) we try to manage it by reduction of vulnerability of site and of facility components, i.e. constructions and equipment taking into account seismic hazard characteristics and data on site and facility. From the viewpoint of management of society it is only one reasonable way for human kind to use the ALARA (as low as reasonably achievable) principle.

The protection of critical facilities against earthquake impact consists in the following strategy:

- on the basis of seismic hazard assessment, assessment of physical characteristics of earthquake phenomena (median of possible courses of ground accelerations in real case) and the critical facility design there are determined the vulnerabilities of components, systems and constructions against earthquakes by defined way,
- the selection of measures by which the vulnerability of important parts of critical facility is reduced in order that the earthquake impacts became accessible. It is necessary to note

that in practice there are only implemented measures that are not long-term distinctly uneconomical.

Tasks that must be performed for the seismic safety assurance (Davidovici 2000) are to remove:

- gaps in knowledge because at practical applications only simplified assumptions are taken into account,
- discrepancies between theory and used technical solutions,
- human errors at designing, construction and operation of facilities (for prevention the quality assurance must be done at all steps of facility use).

Analysis of professional literature shows that the seismic safety assurance starts in the siting (selection of building site), it continues in the design process phase, construction and operation of facility. Former philosophy of facility seismic safety in the siting period was based on suitable site selection. E.g. in the Czech Republic is the legal rule (Vyhlaska 215/1997 Sb.) stipulating:

- To exclude sites:
    - for which the maximum intensity of safe shutdown earthquake is greater than 8° MSK-64,
    - that are in the zone of active or seismoactive fault, with a fault manifestation on the surface, with present deformation of surface and with possibility of origination of accompanied faults. The width of this zone is determined by geological survey,
    - the stability of which can be up to the depth important for construction bedrock damaged by geodynamic phenomena of soil liquefaction that originated as a consequence of earthquake with a level of safe shutdown earthquake.
- Carefully evaluated sites for which the safe shutdown earthquakes is greater than 7° MSK-64.

Since 90s there has been more and more forced into practice the requirement that the technological facility must be located in place in which it is need, and that the seismic safety must be ensured by suitable selection of design the necessary seismic resistance is ensured.

The technical measures leading to seismic risk reduction are costly, and therefore, for their selection the stringent rules hold. Firstly, the studies are directed to:

- define relevant seismic input for constructions, systems and components, i.e. the input data that consider the site seismic hazard value and ensure that expected seismic risk does not reach accessible level,
- define frequency range, that must be specially followed during the facility operation and to which to tune up the seismic instrumentation that belongs to the facility I & C ,
- determine the strategy for the case of impact of earthquake with risky parameters, i.e. earthquake with more unfavourable characteristics than those that are considered in design.

Because earthquake impacts on each civil or technological facility depends on the earthquake size and on the earthquake characteristics, in practice it is used:

- in the design process the consideration of seismic loading (i.e. loading caused by earthquake with a given size and frequency characteristics) by the way that is combined with other loading that are stipulated by norms. On the basis of site seismic hazard value and site earthquake characteristics there are determined limits, so called design earthquakes (having a different denotation, e.g. DBE (design basis earthquake), SSE (safe shutdown earthquake)). These values are determined either according to norms or by specific procedures. By this it is ensured the integrity and functional capability at the earthquake impact, i.e. no unfavourable phenomena occur,

- the system of inspections that check up if at the earthquake impact (corresponding to site seismic hazard) there cannot occur phenomena that are not accessible or in the case of change of demands at older facilities there is assessed if these facilities are in accordance with new requirements or which seismic loading the facilities withstand in reality.

Technical measures for the seismic risk reduction mean:

- selection of suitable construction elements, materials and mounting ways,
- selection of suitable mounting solutions,
- using different supports, arming, limiting equipment, anchorage and amortisers,
- use of protective barriers, protective systems,
- at electric equipment use the different means for the case of occurrence of unexpected effects,
- at I & C elements use the suitable software containing instructions for interventions at occurrence of defects that are possible at earthquake impact.

The protection against earthquake, i.e. the application of appropriate technical measures, is codified at each country by legal rules, because if it is not stipulated by legal rules it is not respected. The respect of given measures is important in cases when the financial cost decide, because it is known that the upgrade of seismic resistance of facility for one degree of macroseismic scale means double costs. The author's practical experiences show that the big discussions with investors are usually connected with the documentation of value of seismic hazard, investors want to reach the smallest possible value of seismic hazard, in order to reach least possible costs.

4.7. Seismic Inspections

Seismic inspections are important instrument of seismic risk management. They might be performed in both, the civil and the technological facilities. State authorities ensure inspections in civil facilities.

Inspections in technological facilities (walkdowns) for the assessment of seismic resistance are realised by the ad-hoc composed team according to proposal of state regulatory body that prepares inspection and that knows the weak (vulnerable) items of facility in which the inspection is under preparation. Selection of specialists is carried out according to the inspection aim. In each case it is necessary the participation of specialist for the electric equipment (relay, battery etc.) because in this domain earthquake impacts are usually underestimated (Budnitz 1995). Priorities in the aims of inspections are stipulated according to the facility component vulnerability. At the assessment of system vulnerability it is put emphasis on the fact that at the impact of upper limit earthquake it is necessary to maintain in some range the function of principal components and by this way the function of whole system. From this viewpoint there is assessed on the one hand the seismic resistance of components and on the other hand the seismic resistance of whole component sets (e.g.

mechanical systems and components, electric systems and components, I & C systems and components).

At seismic inspection we perform for important components the comparison of their characteristics related to seismic resistance with the reference characteristics of the experience database suitable for this case. If component characteristics values either related to physical state of component or related to time factor, are out of interval limits stipulated by experience database, the component exchange is recommended. Inspections also follow actual state of equipment (anchoring, possible interactions etc.).

Inspections are either regular or ad-hoc. The second one follows immediately the earthquake or other disaster impact. From the practical reasons in some countries there were in some branches performed for inspections with defined aims the questionnaires that content principal questions from the viewpoint of seismic resistance of critical components, several possibilities of assessment and notes. Each inspection is concluded by protocol. In many countries there is required in order that the protocol may include the proposal of remedy measures.

At the inspection preparation, there are step by step stipulated its aims, procedure, list of verified components, group of specialists, criteria for walkdown and for documentation of results. Into the inspection team there are also included the necessary specialists of facility personnel. Into the list of components that will be verified during one inspection it is as a rule selected from 300 to 500 equipment items.

The aim of seismic inspections is to asses the seismic resistance of selected civil and technological facilities. At inspections there are used direct and reverse methods.

The direct methods repeat the designing process of facility and they are consists of the following steps:

- check up of correctness of value of site seismic hazard and of seismic terms of references that were used in the design for the assurance of resistance of constructions and equipment at earthquake impact,
- check up of correctness of determination of seismic risk with regard to the model of civil or technological facility,
- check up of correctness of classification of constructions and equipment into seismic categories,
- check up of requirements of seismic resistance of constructions and equipment classified into the first or second seismic categories,
- at constructions of the first or second category of seismic resistance the comparison of required and actual seismic resistance,
- recommendation of measures for facility seismic safety upgrade.

Reverse methods that are based on the answer to question “how strong earthquake the given facility withstand?” consist in the following: on the basis of walkdowns reasons and the design documentation, the constructions and equipment are divided into seismic categories. The determination of seismic resistance of individual constructions and equipment ranked into the first and second category is performed by computation, test or analogy respecting data in the experience database. By aggregation of obtained data it is determined seismic resistance of facility, i.e. the size and response spectra of earthquake to which the facility is resistant without disruption of functional capability and integrity of important constructions and equipment. This value is compared with actual site seismic hazard value and appropriate conclusions are stipulated, e.g. there are selected technical means and measures for the seismic upgrade of important constructions and equipment.

At operating facilities there is comprehensibly only possible to use reverse methods for assessment of seismic resistance of constructions, mechanical, electrical and I & C components. Neither technically nor financially it is not possible some constructions or equipment to exchange or maintain, and therefore, the attention is only concentrated to constructions or equipment that are safety related (US NRC 1980). At searching weak (vulnerable) items of facility there is used the methodology based on the logic tree that is obtained by aggregation of logic trees created by group of experts (minimally three).

Special inspections as a part of seismic resistance of nuclear facilities are required in many OECD countries. At these inspections the affects of ageing have not been considered yet.

5. Seismic Engineering

The main task of seismic engineering as a technical discipline, is to design antiseismic constructions that are resistant to earthquakes with size and characteristics that do not exceed the defined limits. In practice it means to ensure in order that the earthquake contribution to the total risk of civil or technological facility may be negligible.

Engineering activity begins with the site selection (siting) when for site it is determined the site seismic hazard, the character of expected strong ground motions including determination of ground instabilities, that might lead to ground liquefaction, rockslides or landslides or to similar phenomena, and by this to the increase of seismic facility risk. Siting activities are followed by determination of design and its peculiarities (reflecting actual site conditions), construction and operation of facility, and therefore, the seismic engineering is composed of a lot of branches that are mutually more or less linked.

On the basis of knowledge of harmful impacts of strong earthquakes and of measurement of dynamic response of constructions to artificially produced shakings (vibrations), there have been constituted special norms that determine the selection of construction materials, mounting technologies and use of antiseismic mounting elements (e.g. dampers, different mechanical supports and ways of anchorage). These items depend on actual conditions and on technical and financial possibilities of investors and on force of state administrations.

Seismic engineering has a great importance at design process of dams, nuclear facilities, industrial and military complexes, mines, high-rise buildings, hospitals, schools etc. The special branch was established in connection with the construction of technological facilities such as nuclear power plants, chemical plants, storage of hazardous and toxic materials etc., because in these cases there is dealt not only with construction protection but also with the preservation of functional capability of selected technological equipment. It is necessary in order that these equipment at strong earthquake impact may be capable to shutdown technological processes and to keep them in safe state, e.g. at nuclear power plants it must be ensured the safe reactor shutdown, the remove the residual power of reactor for a sufficiently long period, the safe handling with appropriate radioactive leakage (it must not exceed the limit values stipulated by the special regulation).

Knowledge summarised by analysis of earthquakes in the last decade of the 20th century show that mechanisms and manifestations of earthquake are very various. It causes that some measures codified in technical norms and standards seem to be ineffective up to dangerous (Prochazkova 2001). On the basis of this learning there are developing new more perfect measures. For general overview we present here the data showing on the one hand the knowledge development and on the other hand assessment of different ways that were tested.

Update level of seismic engineering is defined on the one hand by principles that are codified in norms and technical standards and on the other hand by knowledge and experiences given in professional papers. It is clear and understandable that level determined by codified legal rules is lower than level stipulated by professional papers.

5.1. Knowledge Level Stipulated by Seismic Norms

With regard to author's experience there are mostly given here the principles using for nuclear facilities. It is possible to use them for other facilities (civil or technological) as model, taking into account that special requirements connected with technologies must be specified in such way that fit for actual facility.

Safety level of nuclear facilities is determined on the one hand by technical parameters of facility and on the other hand by assurance of protection against external phenomena. Among the external phenomena that are considered very risky belong earthquakes. Present level of knowledge in seismic engineering is summarised in the IAEA safety guide (IAEA 50-SG-D15).

- It defines two types of accidents, namely:
    - design basis accidents, at which there are occur phenomena and events to which the nuclear installation is dimensioned by design,
    - severe (beyond design) accidents, at which there are occur phenomena and events that may result to serious core degradation and consecutively to inaccessible impacts on environment.
- It stipulates the term "accident management" that means the application of set of measures that ensure at:
    - origination of any accident scenario (it means event tree) there are not exceeded the design parameters,
    - severe accident there is not started the core degradation,
    - origination of core degradation the nuclear installation returns to control (safe) state and the accident impacts start to be mitigated.
- It defines seismic categories of constructions and equipment by this way:
    - category 1:
    - constructions and equipment that may directly or indirectly cause the accident conditions,
    - constructions and equipment that are connected with reactor shutdown, the criticality monitoring, maintaining the core in sub-critical state and with a remove of residual heat for sufficiently long time,
    - constructions and equipment that may lead to the release of radioactive substances in the quantities that accessible limits for external and internal radiation exposure, stipulated according to valid norms of radiation safety, are exceeded,

- category 2:
  - constructions and equipment that do not belong to the category 1 and that must forestall to radioactive substances release beyond the normal operation limits,
  - constructions and equipment that do not belong the category 1 and that mitigate such accident situations that may last so long time that it is appropriate probability of occurrence of earthquake with a given size,
- category 3:
  - constructions and equipment that do not belong to the categories 1 and 2.
- It specifies the loading combinations by this way:
  - L1: loading caused by normal operation of nuclear facility,
  - L2: additional loading caused by extraordinary events in the nuclear installation operation,
  - L3: additional loading caused by accidental conditions in nuclear installation.
- It stipulates the requirements for seismic design of nuclear facility as follows:
  - seismic category 1: loading combination = L1+SSE (safe shutdown earthquake)
  - seismic category 2: loading combination = L1 + DB (design earthquake),
  - L2 and L3 must be combined with seismic loading if seismic loading is high probable, i.e. seismic category 1: loading combination = L3 + SSE.
- It summarises the principles for minimisation of seismic impacts by this way:
  - to situate centres of gravity of all constructions so low as it is practically possible,
  - to select ground plan of construction and ground plans of individual floors so simply and regularly as it is practically possible,
  - to avoid to protruding parts (lack of symmetry) of constructions so simply as it is practically possible,
  - to create centre of construction stiffness on individual levels (floors) so closely to centre of gravity as it is practically possible,
  - to use antiseismic systems (i.e. protection systems) and equipment,
  - to reduce undesirable movements (interactions) among constructions,
  - to prevent that equipment and its supports might have near eigen (natural) frequencies,
  - to avoid that building foundation might be located in different ground layers (i.e. in layers with different properties),
  - to use very simple arrangement of constructions and simple links among constructions that technology facility seismic analysis may be facilitated,
  - to upgrade seismic behaviour of pipelines and equipment connected with buildings,
  - to anchorage technological equipment,
  - to perform correct links of buildings with ground taking into account ground properties,

- to design and mount constructions so symmetric and balanced in order that it may be reached optimum stiffness, optimum loading and weight distribution with minimum torsional effects,
- to design and mount constructions so flexible in order that origination of brittle ruptures may be forestalled,
- to ensure in order that all links may behave as desirable (as it is in design stipulated),
- to ensure in order that equipment may be sufficiently compact in order that it must not overturn at earthquake impact, in order that it must not origin collisions of neighbouring equipment and in order that on pipes may be located the barriers against origination of nodes during shaking and vibrations,
- to ensure in order that a special attention may be concentrated to parts that are important for mechanical integrity and functional capability.

- It determines way of seismic qualification of constructions and equipment performance, i.e. the judgement of capability to withstand given earthquake level by:
  - analysis,
  - testing,
  - experiences considering,
  - comparison.
- It specifies the seismic qualification performance:
  - directly on the item or on its prototype,
  - indirectly on the model or prototype in lower scale.

The ASCE standard (Housner, Chung 1997) used in the USA and other countries divides the constructions (civil facilities) into three groups according to importance:

- I. – it is required that construction must safely withstand earthquake,
- II. – it is required that construction must withstand earthquake at presence a lot of people,
- III. – it is required that constructions important for society (hospitals, schools) must withstand earthquake.

At designing these constructions it must be taken into account the loading combination: construction weight + equipment weight + people weight + loading caused by earthquake, wind and precipitation. Process of design of facilities with high technological risks (storage of hazardous and radioactive substances, chemical and nuclear plants etc.) is performed according to special rules. It must be followed requirements: not to damage at design values of natural disaster and not to lost functional capability at extreme values of natural disasters (e.g. US NRC, US DOE etc. rules).

Analysis of norms and technical standards codifying the process of design and construction of antiseismic buildings shows that aim of all rules is near the same but real formulation of requirements depends on national legal customs and on technical traditions. Tabular technical descriptions of used ways of technical design and used construction elements are e.g. in work (US DOE 1991).

Davidovici (2000) on the basis of analysis of norms for civil facilities construction dealing with seismic safety assurance specifies gaps in knowledge and shows that at practical applications, i.e. in seismic norm we only used simplified assumptions as follows:

- share (S) waves propagate vertically in the bedrock,
- bedrock is composed of horizontal layers,
- motions induced by earthquake are similar at all parts of construction,
- motions induced by earthquake only followed two main directions in buildings (vertical and horizontal),
- design earthquake is described by the mean response spectra determined for free surface,
- building is isolated, i.e. its interactions with buildings in close vicinity are not taken into account,
- building construction is simple (experiences show that only the most simply constructions have a chance to withstand earthquake and that we are not able to understand behaviour of complicated construction at earthquake impact),
- building is located on the free field surface.

5.2. Update Level of Knowledge Defined by Recent Professional Papers

Present level of knowledge of seismic engineering is described by papers presented at the 12th World Civil Conference on Earthquake Engineering that held in Auckland (New Zealand) in January 2000. From papers presented it follows:

- Statistics of victims at earthquakes in the 1900-1976 period (Arya 2000) shows that in the 1900-1976 years there were killed at earthquakes ca 2.66 millions of people, i.e. earthquakes caused more victims than other natural disasters. In the 1947-80 years at 180 strong earthquakes there were killed 358 980 people in Asia, 38 837 in South America, 30 613 in Caribbean region and in Central America, 18 232 in Africa, 7 750 in Europe and 137 in North America. Therefore, the author concentrates to the reduction of seismic risk of ordinary buildings in developing countries. During the IDNDR the specialists stipulated critical elements of constructions and by help of norms and technical standards introduced into practice the procedures using more safe technological elements and procedures. The following lacks were found:
    - no links among individual parts of buildings,
    - among building parts there are non filled (empty) vertical fissures,
    - building walls are not levelled to vertical position,
    - among bricks or stones in vertical walls are fissures,
    - non stable constructions are not fixed (anchoraged),
    - use of dry bricks leads to disintegration of brick or stone works at loading.

  For buildings at developing countries there were during the IDNDR stipulated technological measures leading to seismic resistance upgrade taking into account the financial possibilities of local population.
- Sustainable development of human society may be only assured if the equilibrium between human society and environment is assured, i.e. if technological facilities and infrastructures must not lead to increase of risks that are caused by natural disaster hazards

that are possible at given site (Matingly 2000). To the vulnerability increase it also contributes the big concentration of people, and therefore, a separate problem is created by megacities. Regarding to this viewpoint the attention in developing countries must be concentrated to territorial planning and to population training. During the IDNDR there were in this domain realised projects as Quito (Ecuador) and Bogota (Columbia). Into practice there were introduced actual antiseismic measures, emergency plans and the big cities population was trained.

- Seismic design is also necessary in zones with middle and low seismicity (PGA = 0.07 g – 0.10 g), i.e. in zones in which damages may be only caused by several earthquakes (Pinto 2000). To such regions the Europe (especially Central and Northern) belongs. In these regions the introduction of seismic design into practice mainly depends on the political decision-making. At present this type of design is only required in countries with advanced economies, and therefore, big damages threaten in developing countries at strong earthquake impact.
- Earthquakes in Loma Prieta, Northridge and Kobe caused big damages of bridges (Kawashima 2000). Author summarises knowledge to disposal and the followed corrections of technical norms for bridge constructions. Into practice in Japan there have been introduced the non-linear dynamic analysis of bridge response and the methodology for considering the soil liquefaction under the bridge piles.
- Buckle (1995, 2000) states that only in the last 25 years the buildings are successfully and consciously designed so, that they withstand strong earthquakes. There are used protective systems. At present broad spectrum of these protective systems, from simple passive equipment to fully active systems, is used. Recent known development of element in this domain there are hybrid systems. Passive systems include dampers of mass motion, insulation systems (systems with flexible elements) and dissipaters of mechanical energy. Use of passive systems has a limitation because there are a lot of uncertainties in their behaviour at small and great earthquakes, and therefore, appropriate legal rules for these systems are not so stringent that limits their brooder use in practice,
- Overview of historical development of semiactive and hybrid systems by which the building seismic resistance is upgraded, shows that active, semiactive and hybrid systems originated by natural development of passive systems based on the energy dissipation (Soong, Spencer 2000). Hybrid systems are combination of passive and active systems. These systems process on-line records of sensors (recording construction loading) located on the construction and immediately determine the construction behaviour with aim to upgrade the construction safety by prepared measures, if necessary. Their development has been huge in last twenty years. Big development was reached in the USA, Japan, China and Taiwan.
- Design process of seismically resistant building in last seventy years went through a great development. During last 25 years a big shift in knowledge was done, e.g. it was shown that the construction strength increase does not lead to safety increase and to damage reduction. Development of principles based on design capacity led to finding that the strength distribution in construction is more important that absolute value of design shear stress. It was distinguished that frame constructions of buildings are more resistant to seismic loading, if connecting plastic joints (hinges) are put in beams (in vertical frames) than in columns and if the shear strength is higher than bending strength. In the 70s there was recognised the importance of knowledge of non-elastic construction response at strong earthquake impacts. Into the practice there was introduced the term “non-elastic construction deformation capacity” and by its measure became the construction tightness

capacity. The value of this quantity depends on the factors as are construction geometry, specific loading in the axis direction and specific stiffness. In the computations there were introduced marginal (limit) states and response spectra (Priestley 2000). For the completeness it is necessary to state that computations based marginal states have been used by Russian nuclear facilities designers since middle of 70s (Prochazkova 2000).

- Separate chapter in seismic resistance solutions is created by the problems of lifeline systems (oil pipelines, gas pipelines, water pipelines, canalisation etc.) and also of transfer systems as transport, electrical, communications etc. systems (Kameda 2000). These lifeline systems have a hierarchical structure and encroach broad space. They are composed of big number of components and of big numbers of junctions. Because they assure the service of building sites, they must be constructed in places where they are necessary, i.e. also in places in which the ground properties are unfavourable (sand, sediments, water-bearing soil etc.) that enhances their vulnerability. Author introduce the term "seismic safety of residential complexes". He states that the high attention has been up to now concentrated to the assurance of seismic building resistance, however, small one to seismic pipelines resistance, though the pipelines are indispensable for the functional capability of settlements. Therefore, it is necessary to:
    - understand to seismic behaviour of life important systems,
    - carry out measures for upgrade of seismic resistance of physical systems,
    - carry out measures for mitigation of impacts of their incorrect function under earthquake impact
    - carry out measures for the mitigation of secondary impacts (e.g. fires) that earthquake impacts usually cause.

  The assessment of earthquake impact scenario in Kobe in 1995 shows that earthquake impacts on lifeline systems are represented by cascade model. Therefore, in Japan the norm for lifeline systems respecting this fact, was introduced into practice. This norm divides these systems and their components into seismic categories according to their level in system hierarchy of functional capability and according to their importance.

- According to Holmes (2000) in civil engineering the seismic hazard is considered in the form of elastic response spectra up to now. Non-linear computational methods, necessary for knowledge of actual construction responses, require, however, non elastic response spectra or accelerograms characterising seismic hazard. Recent researches show that the non-linear behaviour of constructions is mainly caused by the interactions between bedrock and constructions. In this domain the decisive parameter is the maximum ground motion duration that is just strongly influenced by the local geological structure of bedrock. From the society viewpoint it is necessary to expect that in practice there are only realised such adaptations of seismic resistance upgrade that are financially accessible, i.e. those at which the final benefit is sufficiently higher than costs for reconstruction.
- Dynamic soil properties in the building bedrock affect the construction behaviour at earthquake impact. The behaviour depends on deformation size caused by earthquake. García, Mendóza and Romo (2000) attribute the main role in these cases to shear soil modulus, in situ stiffness, dynamic stiffness, damping, soil strength limit and rock strength limit etc. Main factors that affect the size of site earthquake impact are:
    - seismic data (earthquake intensity, frequency characteristics of bedrock, shaking duration),

- geological data (local geological structure, bedrock type, soil layer thickness, bedrock stratigraphic characteristics, soil types according to stratigraphic division),
- geotechnical data (characteristics of elastic vibrations of soil layer, impedantion difference between bedrock and upper soil layer, non-linear soil behaviour according to stratigraphic evaluation (including material fatigue in dependence on vibration duration)),
- geometrical data (non horizontal (oblique) soil layering, topography of bedrock, layers configuration etc.).

Local ground response spectra are influenced by all above mentioned factors.

- Trends revealed in the last decade of the 20th century result to the fact, that seismic hazard is determined on the basis of identification of potential earthquake sources that are determined by the correlation of geological and geodetical data with historical seismicity. Empirical models used for seismic hazard determination have a lot of uncertainties, and therefore, into practice probabilistic approaches are introduced. At the deterministic approach application there is for the ground motion characterisation only used one scenario of earthquake impact, and earthquake occurrence frequency does not directly affect the seismic hazard size. At the probabilistic approach application there are considered motions caused by a great number of possible earthquakes and their occurrence frequency is a key parameter of the whole analysis. Ground motions depend on tectonic category of earthquake. There are distinguished crustal earthquakes in tectonically active regions, crustal earthquakes in tectonically stable regions, earthquakes in the subduction zones boundaries, earthquakes in the subduction plates. In tectonically active regions the earthquake foci are connected with fault systems. In tectonically stable regions the earthquake foci are concentrated into seismic clumps that are not connected with distinctive fault structures (Somerville 2000).

6. Conclusion

Present paper summarises results of seismic engineering domain. It does not deal with earthquakes in complete extent. It mainly studies characteristics that pre-determined the size of earthquake impacts on human society and on environment. It follows human capability to mitigate impacts and tries to emphasise the effective measures that humans know.

It is possible to state that plenty of technical information obtained by study of recent strong earthquakes is the base for design of seismically resistant buildings, for upgrading present buildings and for repairs of damaged buildings. Despite plenty of information that has been collected professionals, there is a lack of specific information of domain of technical measures leading to mitigation of earthquake impacts.

In this moment it is clear that it is necessary that governments may ensure the legal rules:

- codifying seismic loading determination and actual civil and technological seismic risk determination,
- summarising criteria for construction and operation of buildings and their equipment,
- specifying methods for determination of seismic hazard, seismic vulnerability and of seismic risk,
- defining principles of antiseismic design.

Above given data show that from knowledge viewpoint and from human population protection viewpoint there are following hot spots:

- society vulnerability with regard to earthquakes drastically increases,
- systems that are used for description of natural disasters origination, to which earthquakes belong, have from different reasons only a low number of freedom degree, and therefore, we are not capable to see causal connections. The consequences of this reality cause that results originating at application of these systems do not fully correspond to reality,
- applied technical solutions correspond to knowledge of time in which they were designed and constructed, and therefore, they grow old and manifest as insufficient in the light of new knowledge and requirements in connection with earthquakes and their impacts.

For the problems removing it is necessary to:

- define the most acceptable strategy with aim to improve understanding the natural disasters that affect the human society,
- consider non-linear phenomena (e.g. ground liquefaction at earthquake impact) at natural phenomena characterisation because catastrophic events occur as their consequences,
- search new and new suitable tectonic solutions that ensure the human society needs and that are financially accessible for society. The best technical measures from earthquakes there are at present constructions with reinforced concrete shear walls and with correctly anchorage equipment,
- apply at society management the fact that the best defence against any disaster (including earthquake) it is well informed society,
- send without interruption information and requirements to politicians because they determine (perform decision-making) the measures against earthquakes. It is really necessary, because during the IDNDR programme interest of politicians and big states was very low. Just during this programme it was shown that indispensable assumption for finding solutions in real country are not so called "direct finances", but:
    - research leading to revealing the disaster causes and characteristics, and to determination of acceptable measures,
    - population training,
    - finances for purposely stipulated measures to which human society understands and which human society accepts into daily life.

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