PRENTIVE ASEISMIC STRENGTHENING:
FROM PROBLEMS AND APPROACHES TO IMPLEMENTATION.

DEPREME KARŞI KORUYUCU GÜÇLENDİRME:
PROBLEMLER-ÇÖZÜMLERE YAKLAŞIM VE UYGULAMALAR

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ABSTRACT

Since 1987 the special Program and System for Preventive Seismic Safety (PRESS) on the Urbanized Areas (UA) have been developed in Russia by KamCENDR. The Preventive Seismic Strengthening of Structures (PRESESS) is an important part of PRESS. The problems, approaches, rules, manuals, design and implementation of the PRESESS for reservoirs, water-towers, dams and bridges are considered. The common approaches and similar questions which concern the strengthening of buildings have been expounded in article [5].

1. Introduction

In [5] the concepts and common insight into the problem of seismic safety and strengthening of existing constructions were presented.

Nowadays the acuity and importance of construction reliability under EQ as well as lessening of the seismic risk on the UA are becoming extremely high [5].

At present there are a lot of structures which have been erected in accordance with the outdated seismic codes or without regard of them; speedy aging, wear and deterioration of existing structures; increase of site seismicity due to the human influence, best knowledge and, as a result, reconsideration of seismic zoning maps and/or soil due to the impairment of soil conditions and many other reasons, which explain and justify the urgency of problems at issue.

In following of [2,3,4] we will discuss the Seismic Safety and Reliability Problems which relate to lifelines (LL) and special structures (SS).
2. Classification of LL and SS.

Practically all main approaches being used for conventional buildings [5] are extended to LL and SS. The implications of LL and SS in the problem of ensuring the seismic safety cannot be overemphasized. Every new EQ is an added reason for implementation of LL and SS in the damage-formating and emergency management on the one hand and, on the other hand, shows their high vulnerability in practice.

As a rule the following can be related to LL:
- systems of heat and energy supply (electricity, gas, fuel, etc.) - ES;
- systems of water supply (including water purification) - WS;
- systems of sewage, recovery and sanitary - SS;
- systems of communication - CS;
- transport systems including:
  highway and railway transport - RTS;
  air transport - ATS;
  water transport - WTS;

Among SS we will consider those potentially hazardous objects the reliability of which determines the possibility of secondary industrial disaster. Within the frames of the present article such SS as nuclear power stations and chemical plants will not be discussed and we will dwell on those SS which are the LL at the same time, i.e. dams, reservoirs of different types, tanks and oil storage tanks, water towers, chlorine stations, etc. According to the mentioned above we will hereinafter define the systems under consideration as LL.

A lot of peculiarities being inherent in LL such as reliability, maintainability, etc., were more or less taken into account when being designed and built. But as the systems the LL in cities, and especially in megalopolises, were being created for many years, the process being both chaotic and planned was influenced by different and sometimes non-coordinated and out-of-date criteria. That is why the up-to-date system approach and new criteria of vulnerability-reliability-risk to ensure the stable functioning of existing LL on the seismic-prone UA are in need, and this task is not an easy one.

3. Distinctions of LL.

Among the peculiarities of LL the design-constructive ones are of the highest importance.

3.1 Extension. Many of LL may be considered as multispans beams the supports of which are large distance apart and in different soil conditions i.e. they perceive different seismic impacts. Even for relatively small bridges the soil conditions and movements of abutments and supports on the river bottom differ essentially.

3.2 Interaction of LL-objects. The design consideration of interaction of LL-objects in liquid environment (bridge supports, marine constructions) or
those containing liquid storage tanks, water-towers, dams, pipelines have additional difficulties. In some cases (dams, marine constructions, etc.) it is necessary to take into account the dynamic U-object-soil base interaction.

3.3. Distribution. Distribution of LL-systems over the large area implies that these systems are placed in rather different conditions and subject to different loads in different time. For example, different distance from the EQ focus may determine diversified and essentially different seismic impacts on different elements of the LL-objects.

3.4. Risk criteria for LL in the seismic - prone UA. Criteria of allowable seismic risk for LL are not clearly defined. The difficulties are determined by:

- extension of LL, dispersal of critical elements and consequently of different subjection to seismic impact in different points of the area of their location,

- lack of distinct requirements to allowable damages of LL that is defined in its turn by maintainability and period of recovery of their functions, their responsibility and the degree of required functioning in emergencies, availability and number of doubling elements of the LL-system, possibilities and degree of secondary damages from the objects.

Further more the extented LL-objects can't be placed outside the seismically dangerous areas that can be avoided when building the conventional structures. For example, marine and oil storage tanks are often placed in the areas the soil of which is subject to liquifaction; electric power lines traverse across the unstable slopes and steep hills which are avalanche and landside dangerous, bridges cross rivers and ravines which are in line with tectonic fractures.

Though every severe EQ carries away a lot of lives and results in tremendous damage mainly through the damages of LL, there are no seismic schools which descriptively shows the possible damages of LL because the unification of LL and their damages are very difficult to be carried out.

All these peculiarities have been more or less regarded when calculating and assessing the level of earthquake resistance (LER), forecasting the vulnerability and damage formation and reaccessing the required reliability and strengthening of LL:

However the problem of complex and comprehensive SR analysis for the LL-system is so multivalent and complicated that is far beyond the scope of this article and requires special presentation.

The aim of the present article is to enlight the problem in complex, to point out the most important peculiarities and the ways for solving the task as well as description of some important theoretical and practical approaches and recommendations.

4. Procedures and approaches to the work.

As for the complex of work it consists, as in the case of conventional buildings, of the works under the risk-analysis (PRANA) and risk management (PRIMA) programs. It is added up from common stages (Fig.1).

Now we will expound the sequence of preliminary works within the frames of PRAMA to ensure the reliability required and optimal allowable risk criteria of the
The System for Preventive Seismic Strengthening of SESURB - "PRESS"
LL-system and its elements distinguishing the peculiarities of PRESS which are connected with LL.

4.1 The certification of existing LL on the UA including the detail description of phisical (PSS) and exploatational (ESS) states of structures, LL mapping and LL DataDase for UA under issue. For these works to be carried out the Manuals have been developed [1,8].

4.2 The estimation of expert LER (EXLER) of each element (individual structures) and the whole existing LL-system. It is one of the most difficult problems, which must be settled for each type of structures separately. Here are the new approaches and up-to-date theoretical models and solutions such as the consideration of extension, spatiality of structures, their interaction with a soil, of significant importance. In accordance with LER the structures can be assigned to one or another class of seismic stability that is reflected in DB and GIS of UA.

4.3 The direct vulnerability assessment of each element of LL-system with regarding both the EQ-impact and possible secondary effects, of distribution over the area and other special parameters of LL-system and, at last, of comprehensive risk analysis of the LL-system. In the process of risk analysis we realize step 5 of the diagram of Fig.1. that is we reveal the place and significance of each structure with the LL-system during the emergency for disaster elimination and assign thr RELER and other required performances of PSS and ESS. As this takes place we must consider the LL-system in a whole together with the officials of the municipal engineering services and civil defence when drawing up the plan of actions on emergency management.

Only after obtaining the comprehensive idea of probable damages in the LL-system and understanding the complete seismic risk we can select the way and method of the risk management (strengthening included) in relation to the whole LL-system and its each element.

4.4 Determination of shortage of LER and risk acceptability of breakdown of LL-system and its elements, i.e. in which risk area each independent unit of the LL-system is placed, what the probable damages or consequences of the calculated EQ impact are and what the level of their admissibility is;

4.5 Making the decision on necessity for reducing the damage risk or losing the LL unit under the EQ up to an acceptable level and selection of ways and methods for managing the risk;

4.6 Finding the technology for risk management and realization of the process. The stages mentioned being similar in idea and aims differ significantly from conventional buildings in their content, viz. determination of EXLER for 4.2 is impossible without regard of LL-objects extension and that fact that the networks, pipeline and bridge supports are located in different soil conditions because of which they are subject to different seismic impacts and react to them in different ways.

When implementing 4.3,4.4 there exist a number of peculiarities: as opposed to the buildings the reliability required is the system parameter; in the LL-system both the key elements with high reliability and minor ones as well as non-recoverable and maintainable LL-elements with various speed of probable reconditioning must be distinguished; vulnerability and reliability of individual elements in the LL-systems
may differ both from each other and from reliability (allowable risk) of the LL-system in a whole; assigning the required reliability of the LL-system and its individual elements is a separate, uneasy and interesting task the solving of which requires to consider the dispersal of the LL-objects in the LL-system. It is in common for the connected large-scale power system the key objects of which are placed at different distances from the EQ focuses (on different isoseists). Here it is very important to obtain beforehand the knowledge of the role and significance of the LL-system in a whole and its stages for the emergency management and elimination of disasters. So both the municipal engineering services and the civil defence bodies participate in determining the RELER.

When making and realizing the decisions 4.5, 4.6 one may meet a significant variance in the ways of increasing the reliability of the LL-system, viz. improving and/or strengthening of some system's elements up to the definite level; building of new doubling and standby elements of the system; perfecting of operation and bettering of maintainability and speed of reconditioning; installation of independent local (off-system) LL-element that reduces the RELER, etc.

5. Examples of strengthening the LL-objects.

5.1 To ensure the seismic reliability required of the heat supply systems for residential buildings, which are of great importance in the event of winter emergency in Petropavlosk Kamchatsky, it was enough to strengthen some supports of the surface pipeline in the places of drastic change of soil condition under the supports and to ensure the possibility of larger displacements of the pipeline at the place of their input in some buildings.

5.2. The main problem for some UA are the water-towers and reservoirs with water in the water supply system as well as the tanks with fuel-lubricant materials which are placed on weak soils in the coastal areas or on the steep slopes above/near the residential area and create a high threat for population.

A lot of efforts have been devoted to solution of this problem which resulted in the patented [7] idea and method of pneumo-seismoprotection of various reservoirs, tanks, water-towers and dams. The method is the decrease of dynamic pressure on the walls of the vessel by introducing the containers with air the volume of which is of 5-10% of the whole content into the liquid. Such system operates either in the mode of sesmoisolation or seismodamping. The design of seismic protection of the surface reservoirs with water and fuel-lubricant materials of volume of 3000 m³, 5000 m³ and 7000 m³ have been developed.

5.3. To ensure the seismic reliability of some bridges on the Baikal-Amur railway it is enough to strengthen the multibolt connection of the span-support fastening. It is these bolts which are the critical element in the complex bridge construction.
6. Conclusions.

6.1. Approaches and solutions for ensuring the seismic reliability and safety of the LL satisfy the general requirements expounded in [5] but they have some specific features which differ from conventional buildings.

6.2. When analysing and managing the seismic risk in relation to LL and SS the application of the system approach is becoming the obligatory. In doing so we must take into account:
- the distribution of LL-system i.e. different remoteness of its elements from the focuses of the EQ;
- the extension of the LL-system (pipelines) and individual LL-objects (bridges);
- the different role of operational significance of the LL-system elements under the emergency situation.

6.3. The obligatory preliminary materials for analysing and strengthening the LL are the compound plans of networks and their management on the UA, DB and GIS which have been received as a result of certification as well as the maps of vulnerability of the LL. When drawing up the latter one should use the method of Estimation and Logistic-Expert System Analysis (MELESA) [3]. In this case the analytic models are combined with the particular DB, experience of exploitation of LL and the principle "The chain is no stronger than its weakest link".

6.4. The developed system approaches and design solutions allowed to choose the key elements in the LL-system, key construction elements in the LL-object and then the necessary level of required strengthening and optimal way and method for it to be achieved.

When managing the risk we apply the well-known principles of "Reasonable Sufficiency", "Economic Expediency" and "Optimum Choice", but instead of the principle "Smoothing and Leveling of Risk" we use the principle "Protect the Vulnerable Spot".

6.5. The developed methods of pneumo-seismoprotection of structures which contain the liquid [7] and the new ways and technology for seismoprotection of bridges [8] allow to manage the SR by effective strengthening of the LL-systems on the UA.

6.6. All results of analysis and management of SR on the UA are reflected in the Disaster Scenarios of the 3-d level (DISC-3) that allow to control the whole process of bettering the LL-system in the sense of its more stable and safety functioning.

REFERENCES


