DEVELOPMENT OF SEISMIC DESIGN CODE FOR OIL FACILITIES IN IRAN

Mohammad Javad Seyedi[1], Shiro Takada[2], Junichi Ueno[3], Yasuko Kuwata[4] and Morteza Bastami[5]

[1] *Civil & Structure Head, National Iranian Oil Engineering & Construction Company, Iran*
[2] *Adjunct Professor of University of Tehran, Iran*
[3] *Managing Director, Research Institute of Lifeline Engineering, Japan*
[4] *Associate Professor, Dept. of Civil Engineering, Kobe University, Japan*
[5] *Graduate student, Dept. of Civil Engineering, Kobe University, Japan*
Email: ueno@lifeline-eng.com

ABSTRACT :

A new seismic design code for oil facilities is being discussed by a research project committee organized by NIOEC (National Iranian Oil Engineering and Construction Company). Present paper shows the basic concept of the new design code which introduces the seismic design methods of an allowable stress design method and a ductility design method depending on the input seismic intensity. After reviewing the current main international design codes focusing on the design spectra, a method to obtain velocity design spectra for the design of buried structures corresponding to the acceleration design spectra for the design of above ground structures has been proposed

KEYWORDS: Oil facility, Seismic design code, Seismic design acceleration spectra, Seismic design velocity spectra, Buried pipeline, Above ground structure

1. INTRODUCTIONG

Many different codes and standards are used in the structural and seismic design and assessment of oil facilities. They have been revised periodically and made them known to public. Many of these codes have been developed primarily for use in the design of buildings in the region. Present seismic specification for oil facilities in Iran has been built up by introducing current codes under the consideration for existing codes and specifications. A new seismic design code for oil facilities is being discussed by a research project committee organized by NIOEC (National Iranian Oil Engineering and Construction Company). Present paper shows the basic concept of the new design code which introduces the seismic design methods of an allowable stress design method and a ductility design method depending on the input seismic intensity. After reviewing the current main international design codes focusing on the design spectra, a method to obtain velocity design spectra for the design of buried structures corresponding to the acceleration design spectra for the design of above ground structures has been proposed.

2. REVIEW OF INTERNATIONAL CODES FOCUSING ON SEISMIC DESIGN SPECTRA

2.1. UBC97

Uniform Building Code (UBC) has been replaced with International Building Code issued by International Code Council in 2000. Originally, UBC97 was used in west coast area of US. 1997 version was final issue of UBC and near-source effects and ground acceleration dependent soil site amplification factors for both short- and long-period structures were introduced. The philosophy is that structures are designed in conformance with these requirements as follows.

a). Resist a minor level of earthquake ground motion without damage.
b). Resist a moderate level of earthquake ground motion without structural damage, but possibly experience some nonstructural damage.

c) Resist a major level of earthquake ground motion of intensity equal to the strongest earthquake either experienced or forecast for the building site without collapse, but possibly with some structural as well as nonstructural damage.

To implement this philosophy, the UBC specifies ground motion criteria, equivalent static force equations, methods of analysis and analysis procedures, load combinations and load factors, acceptance criteria and detailing requirements that apply to essentially all structures and nonstructural systems. The code seismic design forces are established utilizing the concept of inelastic response to reduce elastic seismic forces to design levels.

2.2. ASCE7

In 1988, ANSI combined with ASCE to update and re-designate ANSI A58.1-1982 to ASCE7. Since then, ASCE7 has been updated four times. ASCE Standard 7-05 "Minimum Design Loads for Buildings and Other Structures" provides requirements for general structural design and includes means for determining dead, live, soil, flood, wind, snow, rain, atmospheric ice, and earthquake loads, and their combinations that are suitable for inclusion in building codes and other documents. The earthquake load provisions in ASCE 7-05, based on USGS- zoning map, are substantially adopted by reference in the 2006 International Building Code and the 2006 NFPA 5000 Building Construction and Safety Code. Provisions of all other ASCE 7-05 sections are also adopted by reference by both model building codes including the provisions for calculating wind loads and snow loads.

2.3. Iran Standard 2800

"Iranian Seismic Code 2800" was established in 1989 after the Tabas Earthquake (1978) and Naghan Earthquake (1977). Second version was issued in 1999 after Manjil Earthquake (1990). Third version was issued in 2005 after Bam Earthquake (2003). Design subject of Standard 2800 is the building of RC, Steel, Wooden and Masonry. As a service life of building, 50 years is supposed. In Standard 2800, two level of earthquake is defined.

a) Design earthquake (Strong earthquake)
The possibility of occurrence of this earthquake in service life is less than 10%.

b) Service level earthquake (Low-medium earthquake)
The possibility of occurrence of this earthquake in service life is more than 99.5%.

2.4. Eurocode8

Euro-code (also known as EN Euro-code or EC) is a set of unified international codes of practice for designing buildings and civil engineering structures. They will eventually replace the national codes published by national standard bodies (e.g. BS 5950) after a period of co-existence. At the moment some Euro-codes are still in a trial phase, so they are characterized as ENV instead of EN until they are officially adopted. Additionally, each country may have a National Annex to the Euro-codes which will need referencing for a particular country (i.e. The UK National Annex). The complete suite of structural Euro-codes are being produced by the Comité Européen de Normalization (CEN), the European committee for standardization. EN presently has 29 members including the UK. There are ten Euro-codes, each involves a number of parts. EN 1990 gives all the operative material independent rules (e.g. partial factors for actions, load combination expressions for ultimate and serviceability limit states), and therefore EN 1992 to EN 1999, which do not provide material independent guidance, cannot be used without EN 1990.

Whole series of Euro-codes, two level of required performance ("no-collapse" and "Damage limitation") is supposed and design input is prepared respectively.

2.5. Seismic design code for high pressure gas facilities (KHK, Japan)

In Japan, The High Pressure Gas Safety Institute of Japan (KHK) was founded in1963 under the "High Pressure Gas Safety Law (Law No. 204 of June 7, 1951)". Competent Authority was The Ministry of Economy, Trade and Industry (MITI). High pressure gas facilities were designed against earthquake subjected to Japanese Building Code before 1960s. Under the experiences of Niigata Earthquake (1964) and Tokachi-oki Earthquake (1968). The Safety Division of Industrial Location and Environmental Protection Bureau of the Ministry of International Trade and Industry issued the Seismic Design Code (Notification No.515, 1981). All of the new high pressure gas facilities in Japan should be designed by the titled code effective after 1982 as technical standards. Kobe Earthquake (1995) caused the damage for some pipings and foundations, but little of towers, vessels and tanks. Then "The Basic Plan for Disaster Prevention" was revised by the Central Disaster Prevention Council, July 1995. It requires the introduction of 2 steps earthquake assessments for the facilities. Design base earthquake shall be both "probable strongest earthquake in the service life of the facilities" called "Level1 Earthquake" and the "probable strongest earthquake even though with low probabilities" called "Level2 Earthquake". Therefore titled Seismic Design Code was amended (March, 1997).

3. SEISMIC DESIGN PROCEDURE FOR OIL FACILITIES

Figure 3.1 shows the proposed basic procedure of seismic design for oil facilities focusing on design methodologies and input ground motion. Maximum operational earthquakes (MOE) are ones which have the probability of occurrence once or twice during the service period of the oil facilities. Un- acceptable damage states for the operation of oil facility systems are limited for this level of earthquakes and the system has enough reliability for continuing the operation. Occurrence probability is 50% within 50 years that correspond to 72 years return period.
The maximum considered earthquakes (MCE) are ones which have law occurrence probability and much longer return period than the MOE. The behavior of oil facility system would be in ultimate limit state for this level of earthquake and the total system should be stable even though each element might have damage. Occurrence probability is 10% within 50 years that correspond to 475 years return period. For the lower level of earthquakes such as MOE which has the occurrence probability once or twice within service period of facilities, elements of structural system should not have any physical damage without stopping system-operation. The state is called "Damage limitation state". Any members constituting of the system should be in an elastic state of stress and strain relation without yielding condition.

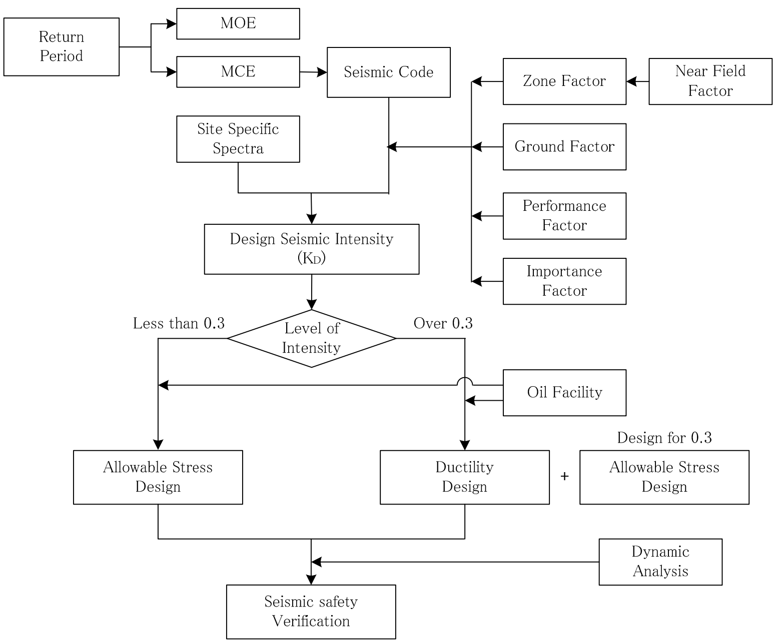

Figure 3.1 Basic procedure of seismic design for oil facilities focusing on design methodologies and ground motion intensity

For the level of earthquakes such as MCE which has the lower occurrence probability within system service period, elements of structural system could be allowed to have minor physical damage, but the stability of the structural system should not be lost. The state is called "Ultimate damage state".
For the earthquake with the damage limitation state, a caused stress in the structural members is compared with

an allowable stress in an elastic range. Generally speaking, the allowable stress design method shall be applied in the case of a coefficient C, which will be explained later, is less than 0.3. Horizontal capacity method is the one to check the ultimate damage state for the capacity seismic horizontal force of structures.
Alternative evaluation method is the one which a member stress is calculated by using an equivalent elastic design spectrum. The equivalent elastic design spectrum is obtained by multiplying a deducing coefficient to an elastic design spectrum. The deducing coefficient is corresponding to a ductility factor or to an energy absorbing capacity of structures.
Ductility factor is checked with an allowable ductility factor. Sometimes, the ductility factor can be expressed in terms of structural strains.

4. METHOD AND RESULTS FOR DESIGN VELOCITY SPECTRA FOR BURIED STRUCTURE CORRESPONDING TO DESIGN ACCELERATION SPECTRA FOR ABOVE GROUND STRUCTURE

Underground facilities are designed based on a response displacement method. In the response displacement method, response of underground structures are analyzed under the input of ground displacements in free field ground at the location of the structures by using quasi-static method in which a dynamic inertia and damping forces are neglected. The free field ground displacement can be calculated by Eqn.4.1.

$$S_V = \alpha_V \cdot A \cdot B \quad \text{(kine = cm/sec.)} \tag{4.1}$$

A in Eqn.4.1 gives a basic seismic intensity in term of acceleration divided by gravity acceleration and B gives response factor depending on a natural period of facility. Then α_V shown in Figure 4.1 gives a conversion factor from structural acceleration to ground velocity.

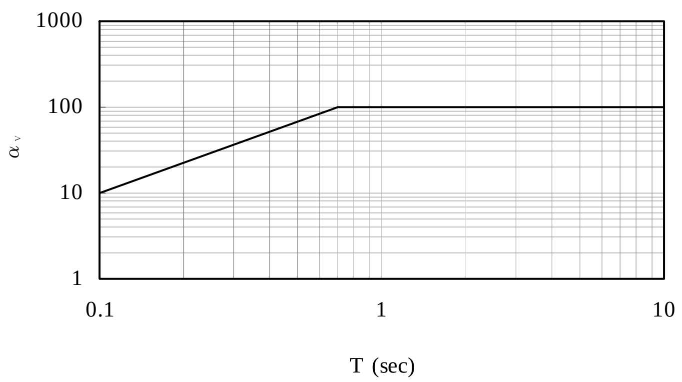

Figure 4.1 Design velocity spectrum for buried structures corresponding to acceleration spectra for above ground structures

Method to obtain velocity spectra for buried structures corresponding to acceleration spectra for above ground structures with Fourier transform method is as follows.
As well known, Fourier spectrum $F(\omega)$ of $f(t)$ is mostly same configuration in frequency domain with response velocity spectrum S_V under the input of $f(t)$. $F(\omega)$ is exactly same configuration with a residual S_V for $f(t)$. The residual S_V means the maximum response velocity calculated for the response after the end of the input wave of $f(t)$.
By using the above characteristics for spectra, we can obtain $f(t)$ compatible to S_A following procedure.

1) S_A can be converted to S_V' by using the quasi-response spectra relation.

2) $f(t)$ (k=1) can be obtained by an inverse Fourier transform of S_V' under the assumption of phase characteristics. Random phase or the difference of phase showing non-stationary shape of amplitude in time history of $f(t)$.

3) $S_V'(k$=1) is calculated by using $f(t)$ (i=1) as the first step approximation.

4) Following error evaluation is done after repeating above procedure up to obtaining the smaller value of ε.

$$\gamma_k = \frac{(S_V)_k^{h=0.05}}{(\bar{S}_V)_k^{h=0.05}} \tag{4.2}$$

$$\varepsilon = \sqrt{\frac{\sum_{k=k_{\min}}^{k_{\max}} (1-\gamma_k)^2}{k_{\max} - k_{\min} + 1}} \tag{4.3}$$

Here, $k_{\max}$ and $k_{\min}$ are the upper and lower boundary of frequencies where S_V' is calculated.

5) The obtained $f(t)$ has enough accuracy giving a target S_V' spectrum. The $f(t)$ is an acceleration time history at ground surface.

6) $f(t)$ at ground surface is converted to ground motion $g(t)$ at the seismic engineering base rock by employing SHAKE program or others taking consideration of ground non-linear relation.

7) Finally, S_V for obtaining ground displacement at the surface layer can be calculated by $g(t)$.

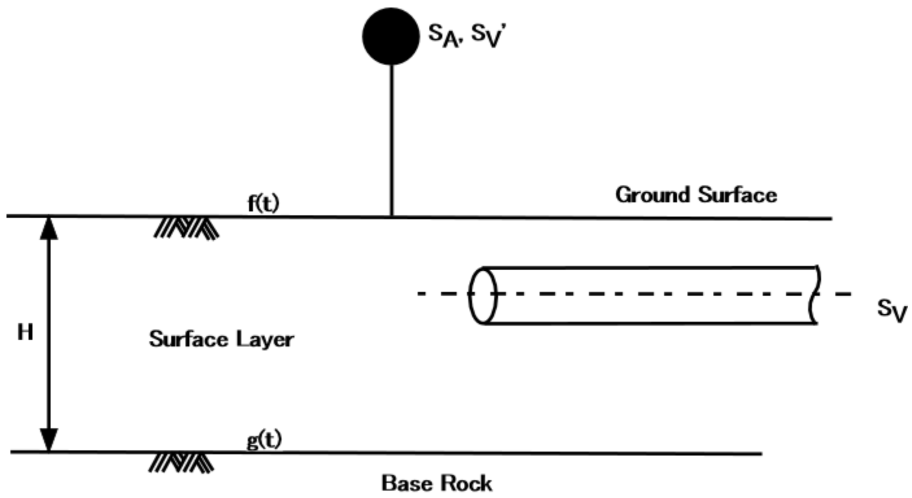

Figure 4.2 Model of surface ground layer and relation of velocity design spectra
for above ground structure and for buried structure

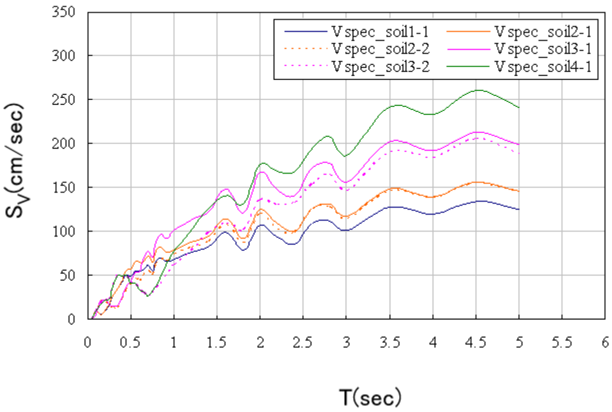

Figure 4.3 Velocity spectra for different soil conditions

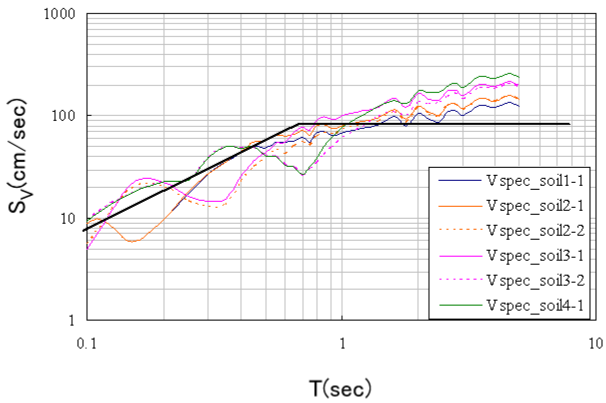

Figure 4.4 Set of simulated spectra for design

Above simulation is done under the parameters of soil conditions of subsurface layer and wave phase when the Fourier spectra in frequency domain are converted to time histories. The proposed design velocity spectrum has been determined to cover the maximum velocity amplitude at 1.0 sec of predominant period of the sub-surface layer.

5. CONCLUSIONS

Present paper has reviewed current seismic design codes used in the world and discussed on the design spectra related with the design method depending on the design levels of seismic inputs. Basically, we can say that an elastic design procedure is employed for lower level of seismic inputs requiring no damage to structures and ultimate damage state is required for higher level of seismic inputs. Based on the results of the review, we proposed the design procedures as Allowable stress design method and Ductility design method depending on the level of seismic inputs. Moreover we proposed a method to determine a design velocity spectrum for buried structure compatible with acceleration spectra for above ground structure taking consideration of the effects of a sub-surface layer.

REFERENCES

ICBO. (1997), 1997 Uniform Building Code (UBC97), ICBO, California, USA

ASCE. (1997), ASCE Standard ASCE/SEI 7-05 Minimum Design Loads for Buildings and Other Structures, ASCE, Virginia, USA

BHRC. (1999), Standard No. 2800 Iranian Code of Practice for Seismic Resistant Design of Buildings, BHRC, Tehran, IRAN

CEN. (1998), EN1998 (Eurocode 8) Design of structures for earthquake resistance, Brussels, Belgium

KHK. (2006), Seismic Design Code for High Pressure Gas Facilities (KHK E012), KHK, Tokyo, Japan

Research Institute of Lifeline Engineering, Inc. (2007), Report for NIOEC, New Seismic design Code of Oil Facility, Osaka, Japan

Osaki, Y. (1994), Introduction of Spectral Analysis for Earthquake Motion, Kajima Institute Publishing Co., Ltd., Tokyo, Japan