CLASSIFICATION AND ALLOWABLE STRESSES FOR CANDU TYPE NUCLEAR PLANT

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I. INTRODUCTION:

The present Indian Standard Code for earthquake resistant design of structures is intended for normal structures only and it emphasises that in case of special and important structures detailed investigation should be carried out. For the nuclear power plant structures located in seismically active zones, detailed analysis has, therefore to be carried to study their behaviour during the design basis earthquakes particularly keeping in view their potential to release radio-active materials to the environment.

II. CLASSIFICATION OF STRUCTURES (1):

For the purpose of seismic design, the structures, systems and components of nuclear power plant are classified into three classes depending on their importance for operation or shutdown of a plant. The importance of the structure is based on two considerations. The first being the economic loss in the event of earthquake occurrence, involving cost of replacement and repairs to such structures as also the loss due to station shutdown. The second consideration is the public health and safety. Special care has to be taken in the design of such structures so that their failure does not result in uncontrolled release of radio activity to the atmosphere. The typical definition of the different classes of structures for typical nuclear plant are shown in Table-I.

III. LOADING CRITERIA:

The seismic forces on the structures are combined with dead loads and live loads and other occasional loads which have a reasonable chance of occurrence.

For the seismic loading, two types of earthquake are considered (2). Safe shutdown earthquake which is an earthquake which causes vibration ground motion for which Class I structures are designed to remain functional. The magnitude
of this earthquake is the maximum conceivable for a particular site.

Operating basis earthquake (OBE) is taken as that earthquake which might reasonably be expected to occur during the life of the plant and Class II structures are designed to remain functional during an OBE. Class II structures may also have a reserve of strength of energy to the extent that these will respond to shocks of intensities comparable to 55% without total collapse.

For seismic loading of Class III structures, the equivalent static seismic co-efficients will be adopted either as per I.S. Code or on the basis of an independent study.

IV. ALLOWABLE STRESSES:

The stress level allowed under operating, live and dead loads are those specified by the applicable I.S. Codes. Generally, structural steel is governed by I.S. 800, concrete by I.S. 456 and prestressed concrete by I.S. 1343. For Class II and Class III structures, when seismic loads are combined with the normal loads, 33 1/3% increase is allowed in the permissible stresses as specified by the relevant I.S. Codes.

For Class I Structures, an increase of 50% is permitted for concrete and the stresses up to yield point are permitted in the case of structural steel. Where the ultimate strength design methods are used, the yield capacity reduction factors as specified in ACI-318 are to be followed. The allowable stresses for all components are to be as per applicable codes such as ASME Section III, Nuclear component. The summary of the load combination and allowable stresses for a typical CANDU nuclear power plant is shown in Table II & III.
V. CONCLUSION

In India, the history of recorded earthquake is very short. There is also a considerable degree of uncertainty in regard to the measurement of earthquake shocks since there are few instrument stations. There are also built-in limitations in the methods of measurements. The formulation of seismic design criteria is therefore, really a difficult task. The continued research and development efforts are required to improve the design techniques to achieve the high level of safety required for nuclear facilities with a corresponding reduction in the conservatism included in the design.

References:

(i) Safety guide 29 - Seismic Design Classification USAEC.
(ii) 10 CFR Part 100 Nuclear Power Plants Seismic and Geologic Siting Criteria, USAEC.
(iii) The paper "Permissible Stresses & Damping factors in Nuclear Power Plants" by Arya, Chandrasekharan, Thakkar presented at the Vth Symposium on Earthquake Engineering at Roorkee.
<table>
<thead>
<tr>
<th>CLASS</th>
<th>DEFINITION</th>
<th>STRUCTURES/SYSTEMS/COMPONENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLASS-I</td>
<td>These are structures, systems and components required for 'Safe Shutdown' of the plant and maintain it in a 'Safe Shutdown' condition and whose failure might result in an uncontrolled release of radioactivity to the environment.</td>
<td>Reactor containment and internal structure, portion of Service Building housing spent fuel transfer duct and storage bay, ventilation system and stack, calandria vault components, PHT and moderator systems, emergency power supply and instrumentation required for Safe Shutdown, air systems and turbine plant protection.</td>
</tr>
<tr>
<td>CLASS-I*</td>
<td>Such structures are designed to Class-I seismic loading and treated as other than Class-I item in all other aspects.</td>
<td>Turbine Building portion housing D.C. sets, emergency power supply, E.O.T. crane etc.</td>
</tr>
<tr>
<td>CLASS-II</td>
<td>These are structures, systems and components which are important to reactor operation but not essential for 'Safe Shutdown' and isolation of the reactor and whose failure will not result in the release of substantial amounts of radioactivity.</td>
<td>Turbine Building portion housing other than Class-I components, turbine plant auxiliaries.</td>
</tr>
<tr>
<td>CLASS-III</td>
<td>These are structures, systems, components which are not directly related to reactor operation.</td>
<td>Administration building, Warehouse.</td>
</tr>
<tr>
<td>CLASS-III*</td>
<td>Such structures are designed to Class-II seismic loading and treated as Class-III in all other aspects.</td>
<td>Service Building portion housing other than Class-I components, pump house, switchyard, cooling water conduits etc.</td>
</tr>
<tr>
<td>STRUCTURE</td>
<td>LOADING CRITERIA</td>
<td>CLASS-I</td>
</tr>
<tr>
<td>-----------</td>
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<td>---------</td>
</tr>
<tr>
<td>CONCRETE CONTAINMENT (SHIELDED OR PROTECTED)</td>
<td>NORMAL LOAD + DSA + DSE</td>
<td>CONCRETE - COMPRESSION AND SHEAR = 0.6 INCREASE IN NORMAL STRESS</td>
</tr>
<tr>
<td>0.5 STRUCTURES OTHER THAN CONTAINMENT</td>
<td>NORMAL LOAD + DSA + DSE</td>
<td>CONCRETE = DSE INCREASE IN NORMAL STRESS</td>
</tr>
<tr>
<td>PRESTRESS CONCRETE STRUCTURES OTHER THAN CONTAINMENT</td>
<td>NORMAL LOAD + DSA + DSE</td>
<td>CONCRETE = DSE INCREASE IN NORMAL STRESS</td>
</tr>
<tr>
<td>STEEL STRUCTURES</td>
<td>NORMAL LOAD + DSA + DSE</td>
<td>STEEL = 25/36 INCREASE</td>
</tr>
</tbody>
</table>

**Notes:**
1. Normal loads include dead load, exception loads, live loads, and loading in class loads shown in loading diagrams for individual structures.
2. DSA = Design Basis Accident
3. DSE = Design Basis Earthquake; 1.4 DSE EFFECTIVE DEGREES FOR CLASS-I STRUCTURES; CORRECTED BASE MARGINS FOR CLASS-II STRUCTURES AND STATIC LOAD CORRESPONDING TO COUNTERPART STATIC COEFFICIENTS FOR CLASS-III STRUCTURES.
4. ALLOWABLE STRESSES FOR NORMAL LOADS SHALL BE AS SPECIFIED IN SECTION 1408H CODE.
5. NA = Not Applicable
### TABLE - III

**Loading Criteria for Components**

<table>
<thead>
<tr>
<th>Operation condition</th>
<th>Class I</th>
<th>Class II</th>
<th>Class III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>Normal load</td>
<td>Normal load + OBE</td>
<td>Normal load + seismic load</td>
</tr>
<tr>
<td>Upset</td>
<td>Normal load + OBE</td>
<td>Normal load + Load due to upset condition.</td>
<td>NA</td>
</tr>
<tr>
<td>Emergency</td>
<td>Normal load + SSE</td>
<td>Normal load + Pipe rupture loads (DBA)</td>
<td>NA</td>
</tr>
<tr>
<td>Faulted</td>
<td>Normal load + SSE + DBA</td>
<td>(or other significant pipe rupture loads).</td>
<td>NA</td>
</tr>
</tbody>
</table>

**NOTE:**
1. Normal load means pressure, dead weight, temperature and other loads as described in the individual design basis reports.
2. Load due to upset condition as described in the individual design basis report.
3. Allowable stresses shall be as per applicable codes (for eg. ASME codes)
4. DBA - Design Basis Accident.
5. NA - Not Applicable.
6. OBE - Operating Basis Earthquake.
7. SSE - Safe Shutdown Earthquake.