Scientific Journal of Impact Factor (SJIF): 3.134
E-ISSN (O): 2348-4470
P-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 2,Issue 12,December -2015

Seismic Qualification Methodology of Nonstructural Components – The Review

Tejendrasinh S. Raol[1]

[1] *R.C. Technical Institute, Ahmedabad*

Abstract : *Currently in any plant, manufacturing shop, assembly shop, maintenance shop etc. has variety of structures, sysytem and equipment comprising of primary civil structure, secondary supporting structure, supporting systems and equipment viz. tanks, vessels, heat exchangers, piping, supports, valves, pumpls, fans, blowers, motors, compressors, diesel generator etc. Seismic Analysis of any plant structural is the calculation of the response of structure of earthquakes. It is the part of the process of structural assessment and retrofit in regions where earthquakes are dominant. There are generally two methods for seismic qualification of various systems. First method is the qualification by testing, in which qualification is performed by shake tabel testing, however shake table testing is not feasible for the systems with excessive weight and large size. Second method is the qualification by analytical methods, in which analytical models are required for developing assembly/component. FEA model is developed and checked under static condition after applying sufficient bondary conditions and loading in this method. Modal analysis is done to find the natural fequency of the sysytem. On the basis of this, harmonic and transient analysis carried out and visualizing the response of sytem under given condition in form of stress, deformation etc.*

Keywords*-Seismic qualification of nonstructural component, Time history analysis, Floor response spectrum, Shake table testing, FEM analysis*

I. INTRODUCTION

Nonstructural building components are elements which are within or attached to buildings provides them essential services and functions. Nonstructural refers to the portion of buildings and facilities that do not perform structural function, that do not resist vertical or internal loads. These components are not a part of the building structural system and are not designed to contribute for resisting the earthquake force. Nonstructural components of building includes: 1) Architectural components: Claddings, partitions, parapets, stairways, suspended ceilings, lighting system etc. 2) Mechanical and electrical equipment: Industrial fan, escalators, pipes and ducts, central control panels, transformers, emergency power systems, fire protection systems, machineries etc. 3) Building contents: Books and shelves, furniture, file cabinets, storage racks etc. In several past earth quakes, it has been found that damage to nonstructural building components can have a higher effect on the safety of occupants and functionality of facilities, loss of properties. Therefore, nonstructural elements should be designed and analyzed to resist the seismic forces or seismic relative displacements depending on their nature. When a building is subjected to an earthquake ground motion, the building can amplify this motion, resulting in floor accelerations higher than the peak ground acceleration (PGA). Mechanical, electrical or other component equipments are required for system functionality. These components are normally heavy and sometimes large in size. Several conditions can increase the seismic vulnerability of this equipment. If equipments are not properly restrained, equipment, machinery and fluid tanks will tend to slide. Massive objects in motion during earthquake can injuries and damage adjacent objects. The motion can also damage connected piping, ductwork and electrical conduits which in turn may lead to other. Serious damage caused by fires, hazardous fluid spills and water leaks. Equipment mounted on vibration isolators is particularly vulnerable because isolation permits resonance during earthquake motions making equipment more difficult to restrain. Slender, tall objects with higher center of gravity can fall over if not adequately anchored. Equipment failures and debris caused by falling object could critically affects the performance of vital facilities such as emergency command centers, fire stations, hospitals, power stations and water supply plants. For protecting the integrity of nonstructural components during seismic events, so there are needs to carry out additional research studies to develop reliable performance based design criteria for nonstructural components and develop methodology and procedure for the qualification of system [1].
Seismic Qualification: While improving the earthquake structural safety of buildings and other structures has received considerable attention in recent years, less effort has been historically directed in improving the performance of critical equipment, equipment systems and processed during and after earthquakes due to nonstructural damage can be much larger than the losses due to structural damage. Over several years, detailed post-earthquake reconnaissance investigations of building failure have provided revealing information on the physical attributes that affect the seismic performance of buildings. The information is presented to highlight potential problems that buildings may face when subjected to strong ground motion. Architectural components, electrical and mechanical equipment mounted within building must be design to withstand the forces and displacements that arise from the seismic response of the structures. The mounting and support of motors, fans and the machinery and equipment need sufficient strength to resists the seismic forces transmitted through these components with the development of performance based earthquake

engineering, harmonization of the performance levels between structural and nonstructural components is necessary. Heavy damage to critical facilities are close to epicenter was certainly in large part attribute to unanticipated high level of ground shaking in the region and the structural damage. However the impact of nonstructural damage on the loss of functionality of critical facilities has been significant, leading to their inability to perform emergency and lifesaving services and tragically loss of live. So it is required that to qualify component/parts or assembly against the ground motion (seismic force) at the stage of design as well as after manufacturing for its sustainability.

II. Literature Review

The seismic analysis should be based on the floor response spectra derived from the response of main primary structural system. The structure is evaluated by time history method to arrive at the floor history and floor response spectra. These floor response spectra are further used for the design or evaluation of the floor mounted nonstructural components. Design consideration of seismic force is accounted at the time of design as well as after designing of component; it is tested for its functionality.

A. C. Pal et. al [2] 1992 has worked on seismic analysis and design of nuclear power plant. Paper shows that an assessment of seismic analysis and design methodologies of nuclear power plant designed prior to or during the 1970 and specially located in the eastern United States is made. Analysis of NPP involved multiple operations in stage starting from generation of free field response spectrum to floor spectrum generation to qualification of supporting structure. Due to lack of analytical technique and field data from earthquake, the analysis and design of these plants were performed with conservative assumption as new data on earthquake is available and new numerical analysis technique are applied to reanalyze these plants, it is consistently revealed that the structure and components are adequate to resist the imposed seismic/dynamic loading.

Pentti Varpasuo et. al [3] 2013 has carried out seismic design and analysis of nuclear power plant structures. The seismic design and analysis of nuclear power plant begins with the seismic hazard assessment and design ground motion development for the site. Necessary steps needed for the seismic hazard assessment and design ground motion development: 1) The development of regional seismic-tectonic model with seismic source areas within 500 km radius centered to the site. Development of strong motion prediction equations. 2) Logic three development for taking into account uncertainties and seismic hazard quantification. 3) Simulation of acceleration time histories compatible with uniform hazard response spectra. 4) The development of uniform hazard response spectra for ground motion at the site. The following two phases in seismic design of NPP structures is the analysis of structural response for the design ground motion. This second phase of the process consists of the steps are: 1) Development of structural models of the plant buildings. 2) Development of the soil model underneath the plant buildings for soil-structure interaction response analysis. 3) Determination of in-structure response spectra for the plant buildings for the equipment response analysis. In the third phase of the seismic design and analysis the equipment is analyzed on the basis of in-structure response spectra. For this purpose, the structural models of the mechanical components and piping in the plant are set up. In large 3D structural models used today the heaviest equipment of the primary coolant circuit is included in the structural model of the reactor building. In the fourth phase the electrical equipment, control equipment and automation are seismically qualified with the aid of the in-structure spectra developed in the phase two using large three-axial shaking tables. For this purpose, the smoothed envelope spectra for calculated in-structure spectra are constructed and acceleration time is fitted to these smoothed envelope spectra.

C. G. Duff et. al[4] 1992 have worked on seismic qualification of nuclear power plant by inspection. Seismic surveys of CANDUPWH nuclear power plant are pre requisite to licensing in Canada. Such surveys provide greater confidence that nuclear plant can safely survive a design basis earthquake. There is no mandatory requirement for such survey has been used to qualify nuclear facility where the original design did not consider current seismic design level or method of analysis. This work considers the possible application of this approach to the seismic requalification of existing U.S. nuclear power plant for higher earthquake levels or analytical techniques different from those originally specified.

D. Witcher et. al[5] 2005 carried out work on seismic analysis of wind turbines in the time domain. The analysis of wind turbine loading associated with earthquakes is clearly important when designing for and assessing the feasibility of wind farms in seismically active regions. The approach taken for such analysis is generally based on codified methods which have been developed for the assessment of seismic loads acting on buildings. These methods are not able to deal properly with the aero elastic interaction of the dynamic motion of the wind turbine structure with either the wind loading acting on the rotor blades or the response of the turbine controller. This works presents an alternative approach, which is to undertake the calculation in the time domain. In this case a full aero elastic model of the wind turbine subject to turbulent wind loading is further excited by ground motion corresponding to the earthquake. This capability has been introduced to the GH bladed wind turbine simulation package. The software can be used to compute the combined wind and earthquake loading of a wind turbine given a definition of the external conditions for an appropriate series of load cases.

Myung Jo Jhung et. al[6] 2010 worked on study on the dynamic response of mechanical component to earthquake. This work presents this study is a theoretical background developed in ANSYS for the time history analysis due to seismic excitation. The effect of the base excitation types on the responses is investigated by comparing response histories between various excitations. In addition to the base excitations, acceleration time histories are applied to the whole model with a base fixed, which is a traditional case used in the transient analysis for the seismic excitation. Also, the response spectrum analysis is performed to generate stresses. All the results of these analyses are comparing with each other and the analysis characteristics are addressed for the responses such as displacement, velocity, acceleration, response spectrum and stress with respect to the various excitation types for the seismic analysis. Finally, the applicability of the analysis types is suggested for obtaining the dynamic responses of the mechanical component due to earthquake. Three types of excitation are applied to the base of the structure for the seismic analysis and their responses are compared with each other. Also, accelerations are applied to the whole structure with a base fixed and response spectrum analysis is preformed. The responses due to these excitation methods are compared, generating the following conclusions when using ANSYS for the time history analysis due to seismic excitations as follows: the only acceptable excitation type is to apply the acceleration time histories to the whole model with a base fixed. When acceleration time histories are applied as a base excitation, the rigid body motion may appear which should be carefully investigated. When velocity or displacement time histories are applied as a base excitation, the corresponding velocity, acceleration or response spectra generated during the analysis may not be correct. It is not recommended to use the command that defines DOF constraints at nodes for the time history analysis due to seismic excitation.

Marcelo Oropeza et. al[7] 2010 carried out work on the seismic response of nonstructural components in case of nonlinear structures based on the floor response spectra method. Investigates the response of nonstructural components in the presence of nonlinear behavior of the primary structure using floor response spectra method (FRS). The effect of several parameters such as initial natural frequency of the primary structure, natural frequency of the nonstructural components (subsystem), strength reduction factor and hysteretic model have been studied. A database of 164 registered ground acceleration time histories from the European strong motion database is used. Results are presented in terms of amplification factor and resonance factor. Amplification factor quantifies the effect of inelastic deformations of the primary structure on subsystem response. Resonance factor quantifies the variation of the subsystem response considering the primary structure acceleration. Obtained results differed from precedent studies, particularly higher primary structure periods. Values of amplification factor are improved. Results of resonance factor highlight an underestimation of peak values according to current design codes such as Euro code 8. Therefore, a new formulation is proposed.

M. B. Sharif et al.[8] 2011 worked on seismic evaluation of equipment supporting structures. It presents, industrial buildings are commonly subjected to forces induced by machine vibrations, earthquake and wind loads. There are number of equipment which have vibrating actions and at the same time tall enough to withstand the wind and earthquake forces. This study deals with the 37m high vessel supported on two store RC frame. The structure was modeled using STAAD PRO 2007. Equivalent lateral forces for model structure were calculated according to seismic provisions for Lahore. The anchorage mechanism between vertical vessels and table top foundation is studied in detail for earthquake induced loading. Anchorage mechanism was designed on ductile failure of stud and bolt. This study revealed that seismic forces on equipment supporting structures are 20 to 30 percentage more than ordinary structures due to low lateral force resistance factor. Design of heavy equipment is primarily governed by large overturning moments. The tilting effect due to heavy equipment loads are catered by proper anchorages to ensure the safe performance under the severe earthquakes. The conclusions will also be useful for the structural designers involved in the design of such industrial buildings.

A. T. Myers et al.[9] 2012 investigated evaluation of the seismic vulnerability of tubular wind turbine towers. There is an overview of some of the important considerations for the reliable evaluation of the seismic risk to modern wind turbine support towers. These considerations include: 1) Turbine specific characterization of the susceptibility of the tower cross-section to local buckling. 2) Site specific assessment of both the strength and characteristics of ground motions .3) Consideration of the response during the operational versus parked condition. Results from a brief analytical study which showed that the spectral impact on the fragility of a wind turbine. The fragility of one particular 80m, 2.4MW wind turbine shown to be the highest for soft soil ground motions and the lowest for firm soil ground motions with pulse-like ground motions having an intermediate fragility. Additionally, the analysis shows that the vulnerability is also dependent on the specific turbine design, even for turbines of similar height. More research work is required and some of it underway to more comprehensively addresses the seismic vulnerability of tubular wind turbine towers and wind farms.

Ion Prowell et al.[10] 2009 have carried out work regarding experimental and numerical seismic response of a 65kw wind turbine. A full-scale shake table is conducted to assess the seismic response characteristics of a 23m high wind turbine. Details of the experimental setup and the recorded dynamic response are presented. Based on the test results, two calibrated beam-column finite element models are developed and their characteristics compared. The first model consists of a vertical column of elements with a lumped mass at the top that accounts for the nacelle and the rotor. Additional beam-column elements are included in the second model to explicitly represent the geometric configuration of the nacelle and the rotor. For the tested turbine, the experimental and numerical results show that the beam-column models provide useful insights. Using this approach, the effect of first mode viscous damping on seismic response is carried out, with observed experimental values in the range of 0.5-1.0 percent and widely varying literature counterparts of 0.5-5.0 percentage. Depending on the employed base seismic excitation, damping may have a significant influence, reinforcing the importance of more accurate assessments of this parameter in future studies. The experimental and modeling results also support earlier observations related to the significance of higher modes, particularly for the current generation of taller turbines. Finally, based on the outcomes of this research, a number of additional experimental research directions are explored.

M. Waqas Anjum et al.[11] 2012 investigated the seismic analysis of electronic cabinet using ANSYS. These gives structural analysis using finite element method gives a preliminary assessment of dynamic behavior of mechanical structures in order to establish the guidelines for designing the experiment. The main objective of this study was to develop a methodology of seismic analysis of electronic cabinets using ANSYS. FEA model of electronic cabinet is developed then; natural frequency of the cabinet is finding by model analysis. Generally, there are two approaches i.e. transient analysis and response spectrum analysis are adopted for the seismic analysis in ANSYS. Since, the given loading was in time domain, therefore, transient structural analysis was preferred for the detailed dynamic investigation of electronic cabinet. The cabinet was modeled with beam188 and its modal analysis was performed rendering the fundamental natural frequency of 8.94Hz, sufficiently close to the experimentally measured frequency of 8.33Hz. Subsequently, transient analyses were performed for horizontal components of ground motion that resulted in peak displacement of 37mm and 28mm at the top of the cabinet which were in good agreement with experimentally measured maximum displacement of 40mm and 30mm at the same location respectively. In addition, peak accelerations obtained from transient analyses were 0.6g and 0.82g while the experimentally measured peak accelerations were 0.8g and 0.89g respectively. It can be concluded that seismic analysis performed in ANSYS produced equivalently reliable assessment of the dynamic behavior of electronic cabinets. Although, ANSYS simulations cannot exclude the experimentations but greatly reduce the design of experiments where time and cost do not allow experimentations.

Hyung-Bin et al.[12] 2012 have work on seismic analysis of an axial blower using ANSYS and a seismic analysis is one of crucial design procedures of an axial blower used in nuclear power plant. The blower should withstand and operate under emergency situations such as earthquake. Modal analysis is performed under seismic analysis and evaluated required response spectrum (RRS) from given floor response spectrum (FRS). A finite element model of the blower is created by using FEM software, ANSYS. Natural frequencies, mode shapes and participation factors are obtained from modal analysis. The RRS is acquired by numerical approach on the basis of the principle of mode superposition. Verifying the structural safety of the axial blower and confirmed the validity of the present seismic analysis results. Data from modal analysis such as modal participation factor and effective mass were used to determine frequency response function and then modal coordinate function. Superposition method is applied to yielded modal coordinate function in order to find RRS. After obtaining RRS, it is possible to determine the safety of the axial blower used in the nuclear power plant. RRS of the axial blower exhibits stable condition and didn’t exceed 10G under most earthquakes. When Y-direction frequency is above 50 Hz, RRS value exceeds 10G. It is known that frequency of the earthquake waves seldom go above 33Hz but, the structure safe should be thought. As the axial blower is weak in Y-direction frequency, it is desirable to reinforce the mounting bolt to the surface in order to ensure safety.

Mohd Zubair Nizami et al[13] 2013 have investigated evaluation of static and dynamic analysis of a centrifugal blower using FEA. Aimed to examine the composites as an alternative to metal for better vibration control. Composites known for their superior damping characteristics are more promising in vibration reduction compared to metals. Blower designed by solid modeling software. The blower is meshed with a three dimensional hex8 mesh is done using HYPERMESH 10. It is proposed to design a blower with composite material, analyze its strength and deformation using FEM software. To evaluate the effectiveness of composites and metal blower using FEA. Modal analysis is performed on both aluminum and composite blower to find out first 10 natural frequencies. Concluded that (a) the stresses of composite blower obtained in static analysis 4.534 N/mm^2 are within the allowable stress limits. (b) The natural frequency of composite blower is reduced because of high stiffness and the lay-up sequence in the blower. (c) The weight of the composite blower is 15 kg which is less than the aluminum blower with a weight of 20 kg. (d) Harmonic analysis results damping effect is more in composite blower which controls the vibration levels.

III. Methodology

According to literature review and working on different non-structural components generalized proposed methodology and procedure for seismic qualification of nonstructural system: For the qualification of equipment requirements should be met are (a) structure integrity and pressure boundary integrity of equipment (b) intended functional operability equipment. These can be performed by analysis or by combination of analysis and test. Qualification for structure integrity and pressure boundary integrity of equipment: Qualification for structure, systems and equipment whether passive or active can be performed by analysis to assess their intended functions in terms of structural integrity and pressure boundary integrity. Qualification by analysis: Qualification of structures, systems and equipment are required to be performed for various loads like load during design, normal and upset condition (pressure, temperature, mechanical cycle, transients), load during emergency and faulted condition (pressure, mechanical), test load etc. The general steps involved are: (a) preparation of the finite element model which represents the equipment adequately. This can be done by selecting proper element for each component and proper meshing of assembly. (b) Identification of applicable load type and its value. (c) Performing model analysis on assembly to find the natural frequency of the system. If first natural frequency of structure/element or assembly is above 33 Hz (or rigid frequency) so analyze it by equivalent static method. (d) Performing static analysis on the assembly. (e) Performs dynamic (Harmonic) analysis on the assembly and determine the response for these loads in term of forces, moments, displacement for various load combination. (h) Comparison of combined stresses and displacement with those that compliance with design and nodal analysis. Qualification for intended functional operability: Qualification of system can be demonstrated by analysis and testing for assessing their intended functional operability. Functional operability by analysis: the seismic displacement as obtained by the analysis shall be combined with displacements/deflection due to other load shall be checked for operational/allowable clearances specified at various component, subassemblies e.g. shaft bearing, impeller casing, stator-rotor, coupling alignment etc. The reactions coming at the bearing locations shall be less than bearing load capacity. Qualification of operability by test: seismic test shall be carried out by mounting equipment on shake table. While seismic motion given to shake table, equipment shall be checked for intended function operability. During the test operating load/conditions of the equipment should also be simulated adequately. The test should be conservatively simulating the seismic event at the equipment mounting location. The multidirectional nature of earthquake should be simulated. This test is depending on the size of component and shakes table limiting criteria. If the size of component does not match then only computer aided seismic analysis done.

IV. Conclusion

Methodology used for the qualification of non-structural component is proposed by this paper. There is restriction on the shake table facility available for the component having heavy size and weight testing after manufacturing is not permitted for that such component. Three methodology qualification by analysis, functional operability by analysis and qualification of operability by test are used for non structural component.

REFERENCES

[1] Patel Mayur D. (2007): Thesis report on comparison of design seismic force on nonstructural component using proposed IS-1893 Draft code, IBC 2000, Euro code8 and floor response spectra, Applied Mechanics Department, LDCE.

[2] A. C. Pal, Seismic Analysis and Desing of Nuclear Power Plant, Earthquake Engineering, Tenth World Conference (1992), pp 4911-4915.

[3] Pentti Varpasuo, Seismic design and analysis of nuclear power plant structures, Engineeirng science Vol. 11 No.3 (2013), PP 10-19.

[4] C. G. Duff, J. D. Stevonson, Seismic Qualification of Nuclear Poer Plant by Inspection, Earthquake Engineering, 10th World Conference (1992), PP 797-804.

[5] D. Witcher, Seismic Analysis of Wind Turbines in the Time Domain, John Wiley Sons Ltd., Wind Energy-8 (2005), 8191.

[6] Myung Jo Jhung and Yong Ho RYU, Study on Dynamic Response of Mechanical Component to Earthquake, Journal of Nuclear Science and Technologoy, Vol.47, No. 11 (2010), pp 1065-1074.

[7] Marcelo Oropeza Pascale Favez Peirino Lestuzzi, Seismic response of nonstructural components in case of nonlinear of nonstructural componenets in case of nonlinear structurers based on floor space spectra method, Springer Science, Bull Earthquake Engg.(2010) 8:387400.

[8] M. B. Sharif, M. Ilyas, M. A. Tahir, A. U. Qazi, S. Ahmed, Siesmic Evaluation of Equipmment Supporing Structures, Pakistan Journal of Science, Vol. 63 (2011), PP 104-107.

[9] A. T. Myers, A. Gupta, C. M. Ramirez, E. Chioccrell, Evaluation of the Seismic Vulnerability of Tubular Wind Turbine Towers, 15 wcee(2012).

[10] Ion Prowell, Marc Veletzos, Ahmed Elgamal and Jose Restrepo, Experimental an Numerical Seismic Respose of a 65 KW Wind Turbine, Journal of Earthquake Engineering, 13, (2009):1172-1190.

[11] M. Waqas Anjum, Basit Khalid and Abdul Rehman3, Siesmic Analysis of Electronic Cabinet using ANSYS, Technical Journal, University of Engineering and Technology, Taxila, Vibrational analysis issue, 2012, PP 1-7.

[12] Hyung-Bin Im, Sewan Kim, Jintai Chung Seismic Analysis of an axial blower using ANSYS.

[13] Mohd Zubai Nizami, Ramavath Suman, M. Guru Bramhananda, Ready Evaluation of Static and Dynamic Analysis of a Centrifugal Blower Using FEA, International Journal of Advanced Trends in Computer Science and Engineering, Vol.2, No.1 (2013), PP 316-321.

