International Journal of Engineering

Journal Homepage: www.ije.ir

Earthquake Evaluation of the Non-Structural Elements in a Thermal Power Plant

F. Nateghi-A.*[a], A. RezaieTabrizi[b], M. Khazaei Poul[c]

[a] *International Institute of Earthquake Engineering and Seismology*
[b] *University of Wisconsin–Madison, USA and former IIEES Graduate student, Tehran, Iran*
[c] *Drexel University, Pennsylvania, USA and former IIEES Graduate student, Tehran, Iran*

PAPER INFO

Paper history:
Received 22 November 2015
Received in revised form 06 January 2016
Accepted 22 January 2016

Keywords:
Earthquake
Evaluation
Nonstructural
Power plant
Equipment

ABSTRACT

Non-Structural elements such as mechanical, electrical and architectural elements always posses serious damage potentials during earthquakes. Degree of damage imposed by the non-structural elements is not usually measured by the physical damages caused, but more so by the amount of the economical and functional disruptions created in a built environment. This phenomenon is enhanced where the functional performance criteria used for the specific site should be of higher standards, meaning for example the "immediate use" criteriaIn order to account for this sort of possible interruptions and plan for the worst case scenario during an earthquake in a thermal power plant in Iran. A study was carried out to evaluate the seismic vulnerability status of non-structural components of the main control building in this power plant. Level one and two assessment methods, namely; rapid and detailed evaluations were used. Three main documents considered for this evaluation were the MCEER, FEMA-310 and FEMA-356 recommendations. The method used and the results obtained which are classified into four hazard levels namely; very high, high, intermediate and low are to be presented in this paper.

***doi**: 10.5829/idosi.ije.2016.29.01a.02*

1. INTRODUCTION

Monetary value of the non-Structural equipments located on the industrial buildings is usually much higher than the value of the structure itself, specially, if the performance criteria is for the immediate occupancy of the plant. In this project, seismic Vulnerability of the non -structural equipments Located on the main control buildings of Hamedan thermal power plant was investigated by the qualitative and quantitative methods.

Hamedan thermal power plant is located in a region with high seismic risk on the North-west of Iran. This power plant with a generation capacity of 1000 megawatts plays an important role in the power generation network of the nation. Its construction began at 1991 and official date of operation has been since 1997. This plant includes several parts namely; boilers, turbine halls, stack, control buildings, water treatment unit, tank farm, cooling tower, fire station and some administrative buildings.

In this paper, only the seismic evaluation of the Non-structural components of the main control building will be presented which are conducted based on MCEER, FEMA-310 and FEMA-356 recommendations.

Parametric studies was performed to identify and assess the effect of different geometric parameters such as layer thickness, tube diameter, tube length and radius of the wave fold accordion on the energy absorption and behavior of multi-layer accordion metallic damper. Also, the specific model provided with the highest energy absorption with the best geometric parameters.

2. DESCRIPTION OF THE BUILDING

The main control building of this power plant has a steel structure which is designed in accordance to the AISC-

*Corresponding Author Email: nateghi@iiees.ac.ir (F. Nateghi-A.)

Please cite this article as: F. Nateghi-A., A. RezaieTabrizi, M. KhazaeiPoul, Earthquake Evaluation of the Non Structural Elements in a Thermal Power Plant,International Journal of Engineering (IJE), TRANSACTIONS A: Basics..Vol. 29, No. 1, (January 2016) 8-13

ASD-89 and ACI-318-83 codes. The control building of the Hamedan power plant consists of two blocks which have the same geometry, structural elements and nonstructural components. In order to minimize the effort, only one of the blocks has been investigated here in this paper. The main duty of these buildings is to control the performance of the main parts of the power plant including: four boilers and equipments located on four turbine halls .

Each story in these buildings is full of several mechanical and electrical equipments. Equipments in the ground floor mostly include tanks, pumps compressors and other equipments which are related to the turbine hall. Equipments on the other stories are mostly, controlling equipments as well as control panels which are very important in performance of the building and keeping the general function in the immediate occupancy regime. Well behavior of the plant is completely related to the performance of these equipments. Finally, equipments at the top story and roof includes equipments which are related to the air conditioning system and naturally have a lower importance in comparison to the other equipments. Therefore, it does not have much direct effect on the immediate occupancy of the building and more generally of the performance of the power plant as whole.

3. DESCRIPTION OF THE EVALUATION METHOD

As mentioned before, seismic evaluation of the Nonstructural components were performed in two qualitative and quantitative phases. For this purpose at first, a seismic risk analysis was performed for the under study site and the earthquake hazard parameters as well as peak ground acceleration and site specified response spectrum were calculated for the return periods of 475 and 2475 years. Site location of the city of Hamedan and the active faults in a region within the 150Km radius of the city is shown in Figure 1.

After establishing seismicity, nonstructural components of the building were classified into architectural, mechanical and electrical groups. For evaluation of architectural components, qualitative evaluation was performed based on FEMA-310 and quantitative evaluation was performed based on FEMA-356 .

For this aim, first some checklists were developed based on FEMA-310 evaluation forms with some modifications to calibrate the forms to the local conditions. All of architectural drawings and construction details were studied and these checklists were filled after visual screening of the building. Then, quantitative evaluation of the architectural components was performed by analytical methods indicated in FEMA-356 for the components which have lateral bracings .

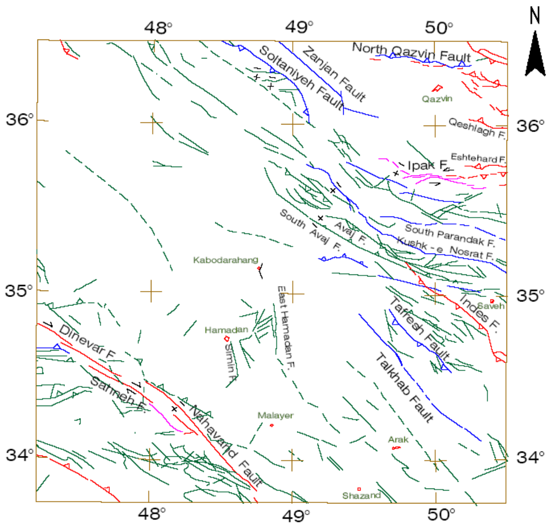


Figure 1. Site location and fault map of Hamedan

For the evaluation of the mechanical and electrical equipments, at first, qualitative evaluation was performed based on MCEER and quantitative evaluation was performed based on FEMA-356. For this aim, at first some checklists were designed based on MCEER evaluation forms with some modifications to calibrate to the local conditions. These forms were then filled out by visual screening for different equipments separately. Equipments which did not have adequate anchorage and lateral bracing were reported as vulnerable equipments. Then, quantitative evaluation of equipments which did have enough anchorage and lateral bracing for stability during earthquakes were performed based on the proposed analytical and loading methods of FEMA-356 for adequacy check of selected types of equipments. Flow chart of the evaluation method used in this study is shown in Figure 2. Paramount vulnerability items in equipment evaluation checklists are summarized here as:

- No anchorage: This problem occurs where there is no anchorage for equipment or anchorage is missed or removed during use of building.
- Poor anchorage: This problem occurs where the anchorage is damaged or appears small compared to the size of equipment .
- Suspect load path: This problem occurs where the structural integrity of equipment is weakened or there is no definite and continues load path from the internal components of the equipment to the anchorage at the base .

- Pounding or impact concerns: This problem occurs when there is a potential for pounding or impact because of low distance between two adjacent equipments.
- Rigid attachment concerns: This problem occurs if attached elements or pipes to equipment don't have adequate flexibility to accommodate generated displacements during motion of equipment in earthquake.
- Interaction concerns: This problem occurs if large items such as Non-structural walls or other components could fall and impact the equipment.
- Vibration isolator concerns: where vibration isolators are used, there should be lateral and uplift restraints. This problem occurs if no restraints exist or they appear to be inadequate.
- Duct support concerns: attached ducting most be properly supported to prevent loads from being transferred to equipment. This problem occurs if there is a question about the adequacy of the duct support.
- Piping support concerns: attached piping, should be well supported to prevent excessive load transfer to the equipment. This problem occurs if long unsupported runs of piping terminate at the equipment.

A sample of the evaluation forms is shown in Figure 3

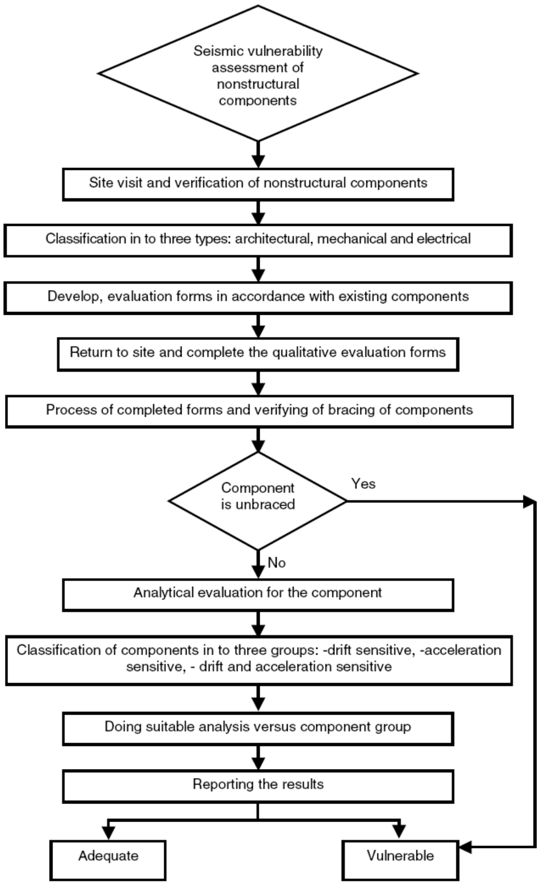


Figure 2. Flow chart used for the evaluation

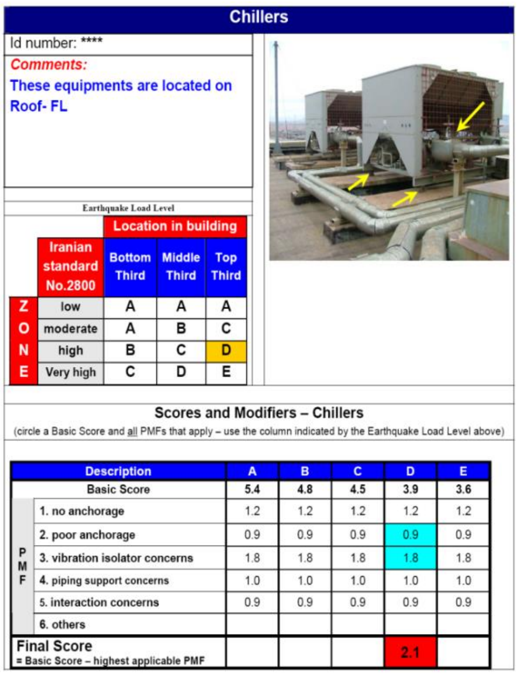
4. EVALUATION RESULTS

In this section, results of the evaluation and some samples of the vulnerability items which were observed during the visual screening of the nonstructural components are introduced [1-7].

Industrial equipments located on the ground floor, were classified as mechanical and electrical equipments only. Most of the mechanical equipments at the ground floor have concerns regarding rigid attachments of the vibration isolator and piping supports that finally classified as low and intermediate hazard levels. Some samples of the concerns related to these equipments are shown in Figures 4 to 7.

Electrical equipments at the ground floor, as well as the distribution panels, switch gears and motor control centers did not posses any important concerns and thus classified as low vulnerable=SAFE hazard level. A sample of these equipments is shown in Figure 8.

Control equipments which are located on different levels of the building were considered as electrical equipments including control panels, switch gears, motor control centers and distribution panels.


Chillers

Id number: ****

Comments:
These equipments are located on Roof- FL

Earthquake Load Level

	Iranian standard No.2800	Location in building: Bottom Third	Middle Third	Top Third
ZONE	low	A	A	A
	moderate	A	B	C
	high	B	C	D
	Very high	C	D	E

Scores and Modifiers – Chillers

(circle a Basic Score and all PMFs that apply – use the column indicated by the Earthquake Load Level above)

	Description	A	B	C	D	E
	Basic Score	5.4	4.8	4.5	3.9	3.6
PMF	1. no anchorage	1.2	1.2	1.2	1.2	1.2
	2. poor anchorage	0.9	0.9	0.9	0.9	0.9
	3. vibration isolator concerns	1.8	1.8	1.8	1.8	1.8
	4. piping support concerns	1.0	1.0	1.0	1.0	1.0
	5. interaction concerns	0.9	0.9	0.9	0.9	0.9
	6. others					
	Final Score = Basic Score – highest applicable PMF				2.1	

Figure 3. Sample of the evaluation forms

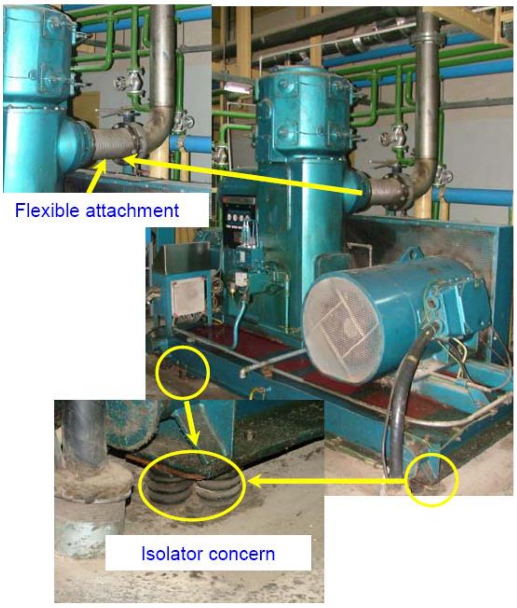


Figure 4. Isolator concern

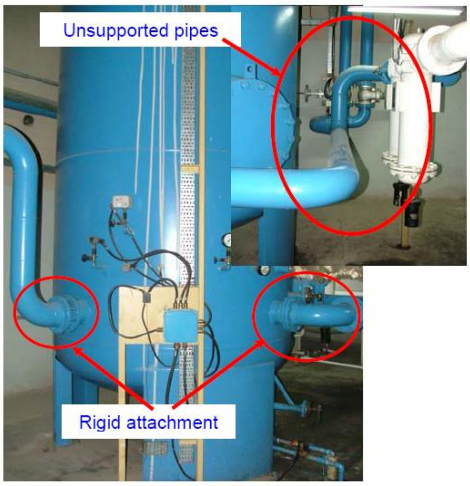


Figure 5. Rigid attachment of unsupported pipes

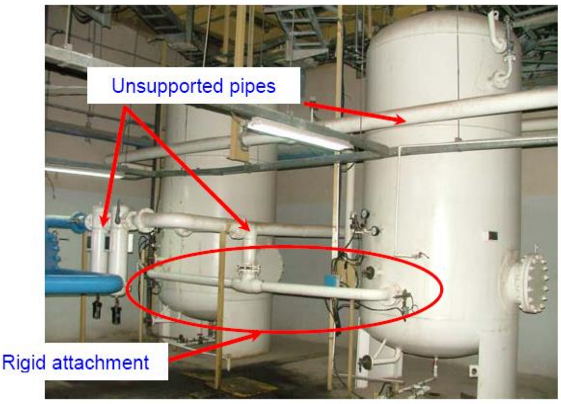


Figure 6. Rigid attachment of unsupported pipes

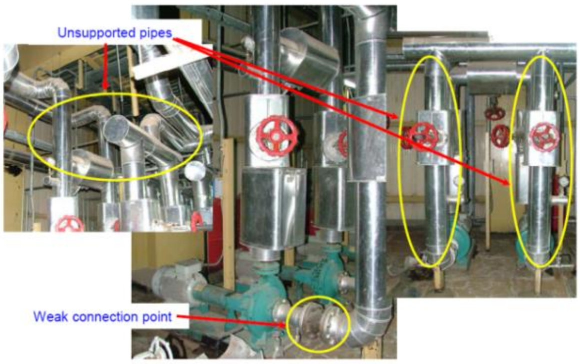


Figure 7. Unsupported pipes which connected by a weak connection point

Figure 8. A sample of electrical equipments at the ground floor

Figure 9. Some samples of control equipments which have a good anchorage

Figure 10. A sample of electrical control equipments which has no any concerns

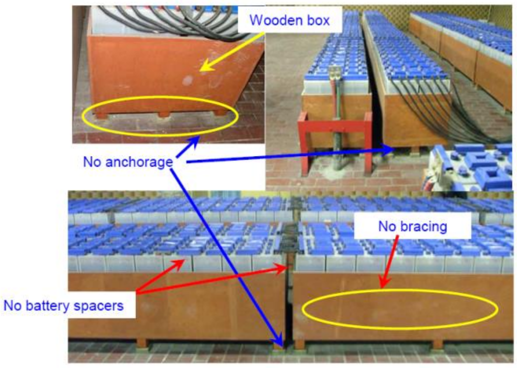


Figure 11. Some samples of battery racks with no anchorage, no bracing and no battery spacers concerns

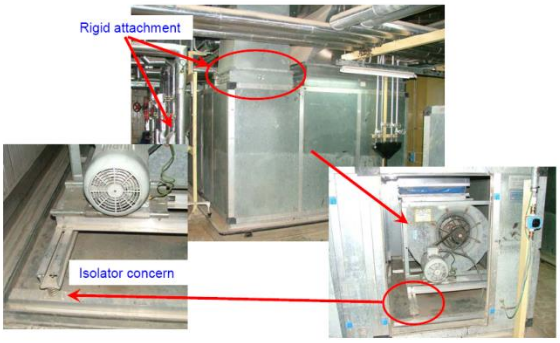


Figure 12. A sample of air conditioning equipments at the end story which has rigid attachment and isolator concerns

Figure 13. Some samples of equipments on the roof level which have rigid attachment and isolator concerns

These equipments were classified as low vulnerable=SAFE hazard level because of the good anchorage and lack of any above mentioned concerns. Samples of these equipments are shown in Figures 9 and 10.

Batteries and racks which exists throughout different levels of the building, were considered as electrical equipments and classified as very high vulnerability hazard level. Because of the no anchorage, no battery spacers, no longitudinal cross bracing and no battery restraints concerns. A sample of these equipments is shown in Figure 11.

Air conditioning equipments of the control building which are located on the end story and roof levels of the building were considered as mechanical equipments which mostly have base isolator concerns and were classified as high vulnerability hazard level. Vulnerability of these equipments does not have important effects on the performance of the building. However, they poses some sort of hazard. Samples of these equipments are shown in Figures12 and 13.

Finally, results obtained from the quantitative evaluation of the nonstructural equipments which specially was done for the control equipments of the building are included; stability and foundation checks. It also indicates that, control equipments of the building mostly are safe.

5. CONCLUSIONS

In conclusion based on the previous sections, main results of this study can be summarized as:

- Control equipments of the building have been classified as safe hazard level because of the good lateral anchorage.
- Rigid attachment, piping support and base isolator concerns are the main problems of mechanical equipments of the building.
- Poor anchorage, lack of battery spacers, longitudinal cross bracing and battery restraints are main problems of batteries and racks that causes high vulnerability of this kind of equipments.
- Architectural components mostly have adequate lateral bracing and thus classified as safe hazard level.

6. ACKNOWLEDGEMENT

This paper is the result of a joint project between Oil Ministry and the Intenational Institiue of Earthquake Enginnering and Seismology (IIEES), which authors are hereby, Acknoledge their support.

7. REFERENCES

1. ACI 318-83, Building code requirements for structural concrete and commentary (ACI 318R-02), reported by ACI committee 318, (1983)
2. AISC-ASD-89, Allowable stress design specification for structural steel buildings, American Institute of Steel Construction, Inc.(1989)
3. FEMA-310, Handbook for seismic evaluation of existing buildings, Federal Emergency Management Agency, (2010)
4. FEMA-356, Prestandard and commentary for the seismic rehabilitation of buildings, federal emergency management agency, (2010)
5. MCEER-99-0008 Seismic reliability assessment of critical facilities, EQE international Inc.(2013)
6. RezaeiTabrizi-Ali, Seismic vulnerability evaluation of main control buildings in Hamedan thermal power plant, final non-structural report, TAVANIR, Tehran, Iran, (2014)
7. Standard No.2800 Iranian code of practice for seismic resistant design of buildings, Building and housing research center, Tehran, Iran, (2015)

Earthquake Evaluation of the Non Structural Elements in a Thermal Power Plant

F.Nateghi-A.[a], A. RezaieTabrizi[b], M. KhazaeiPoul[c]

[a]*International Institute of Earthquake Engineering and Seismology*
[b]*University of Wisconsin–Madison, USA and former IIEES Graduate student, Tehran, Iran*
[c]*Drexel University, Pennsylvania, USA and former IIEES Graduate student, Tehran, Iran*

PAPER INFO

Paper history:
Received 22 November 2015
Received in revised form 06 January 2016
Accepted 22 January 2016

Keywords:
Earthquake
Evaluation
Nonstructural
Power plant
Equipment

چکیده

اقلام غیر سازه‌ای در تأسیسات و سازه‌های نقش بسیار حیاتی را در عملکرد آن‌ها ایفا می‌نمایند.با توجه به حساسیت این اقلام و عملکرد موردنظرآن‌ها در زمان زلزله بخصوص زلزله‌های متوسط و شدید نیاز مبرم برای ارزیابی عملکرد هر یک از این اجزا موردنیازمی‌باشد. در این پروژه برای تأسیسات حرارتی از روش‌های FEMA جهت ارزیابی عملکرد لرزه‌ای اقلام غیر سازه‌ای استفاده شد و بر اساس مطالعات به این روش‌ها جداول عملکردی هر یک از اقلام مورد مطالعه ارزیابی و ارائه شد. در این پروژه چیلرها، ایزولاتورها، لوله‌های غیر متصل، لوله‌های متصل، تابلوهای برق، سیستم‌های کنترلی و سیستم‌های نگاه‌دارنده لوله‌ها بررسی شد جداول شامل چهار گزینه آسیب‌پذیری خیلی بالا، بالا، متوسط و کم می‌باشد که در تزارهای مختلف زلزله برای هر یک از اقلام نشان داده‌شده است روش‌های پیشنهادی عمومیت داشته و در خصوص اقلام غیر سازه‌ای متفاوت در سازه‌ها و نیروگاه‌های مختلفت قابلیت اجرا دارد

***doi**: 10.5829/idosi.ije.2016.29.01a.02*