TRANSACTIONS B: Applications Vol. 29, No. 2, (February 2016) 176-182

International Journal of Engineering

Journal Homepage: www.ije.ir

Seismic Evaluation and Retrofit of Gas Stations: Case Study

F. Nateghi-A.*, A. Rezaie Tabrizi and M. khazaei Poul

University of Wisconsin–Madison, USA and former IIEES Graduate student, Tehran, Iran
Drexel University, Pennsylvania, USA and former IIEES Graduate student, Tehran, Iran

PAPER INFO

Paper history:
Received 22 November 2015
Received in revised form 16 January 2016
Accepted 26 January 2016

Keywords:
Retrofit
Gas Stations
Seismic Evaluation
Equipments
Pumps
Tanks

ABSTRACT

Iran is a country with high seismicity while Tehran, the capital city is home to more than 10 million people which are located on the highest seismic zone of the country. There exist 153 gas stations throughout the metropolitan which are constructed to old building codes with little or no attention to the seismic considerations. This study was conducted under a financial support by the ministry of Oil. First as built drawings were collected and studied in details. A set of new drawings were then created by detailed inspection and also some destructive tastings. This study then looked at the both mechanical and structural properties of the whole structures and their seismic behavior. This procedure was conducted for the main building, piping, tanks, shed structures as well as pumps and mechanical equipments. The loading was considered by the seismic provisions of the Iranian seismic provisions and static load analysis was carried out for the structures. This paper shows the general approach and also the detail procedure used for one such stations.

***doi**: 10.5829/idosi.ije.2016.29.02b.06*

1. INTRODUCTION

City of Tehran is located at the southern outskirts of Alborz Mountain range. This location lies in the highest seismic zone of the nation. Throughout the history this city has experienced many large magnitude earthquakes. Figure 1 shows the location of Tehran and indicates the seismic history of the region. As seen, the city with more than 10 million populations is constantly threatened by a large earthquake .

To this end, city officials are extremely concern about the well beings of the different facilities especially facilities concerning fuel. In order to address this issue, National Oil Company of Iran lunched a research program to study the 153 existing gas stations in Tehran and in case of need, to retrofit them for the possible earthquakes .

In this study, first a site investigation of each station was conducted creating a seismic hazard map for the city. A detail review of the existing drawings and creating as built drawings by opening different sections to control the original drawings then was conducted. After completing the as built drawings, a series of qualitative and quantitative investigations based on structural and finite element analysis was performed resulting in weak link identification for two performance criteria of life safety and immediate use levels. For buildings, life safety and for fuel tanks, immediate use was considered. Based on the analytical investigations then deem-to-comply strengthening details and drawings were constructed. The whole procedures were utilized for the main building, piping and tanks, shed structure, pumps and mechanical and electrical units in each station. This paper will provide details in regards to the procedure, findings and retrofitting techniques which were used to achieve the goals of the project [1, 2].

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

2. RECREATION OF AS BUILT DRAWINGS

As stated above, 153 gas stations were the subject of this study. Attempts were made to work with the original drawings. However, it was soon discovered that first of all, not all stations had drawings and second of all, those which had drawings usually major changes were done during constructions. To address this

Please cite this article as:F.Nateghi-A., A. RezaieTabrizi and M. khazaeiPoul, Seismic Evaluation and Retrofit of Gas Stations: Case Study,International Journal of Engineering (IJE), TRANSACTIONS B: Applications Vol. 29, No. 2, (February 2016) 176-182

problem, a series of points were marked on the structures, mainly the main building and the shed structures which then were opened. Then, Ddrawings of the as built structures were recreated after inspections of the opened sections. Of course, different structures were used in different stations. A typical masonry building with steel framed shed will be present herein for the limited paper length. Pumps, fuel tanks and piping had detailed drawings and were similar in about all of the stations. Therefore, after inspections, original drawings were used for the analysis. Figure 2 shows a picture of a station used for the study. Figures 3 and 4 show the as built drawings for a complete typical station. As mentioned above, building structures were mainly constructed as masonry with Jack-Arch roofs. Some newer buildings also had structural steel framing with R/C joists as roofing system. Both types of structures were analyzed.

3. ANALYTICAL INVESTIGATIONS

3.1. Buildings In this section, a study of masonry walls and behavior of the buildings were analyzed using recommendation by FEMA 356. In plane and out of plane resistance of each wall was calculated as shown in Table 1. A program was developed to consider the in plane and out of plane resistance.

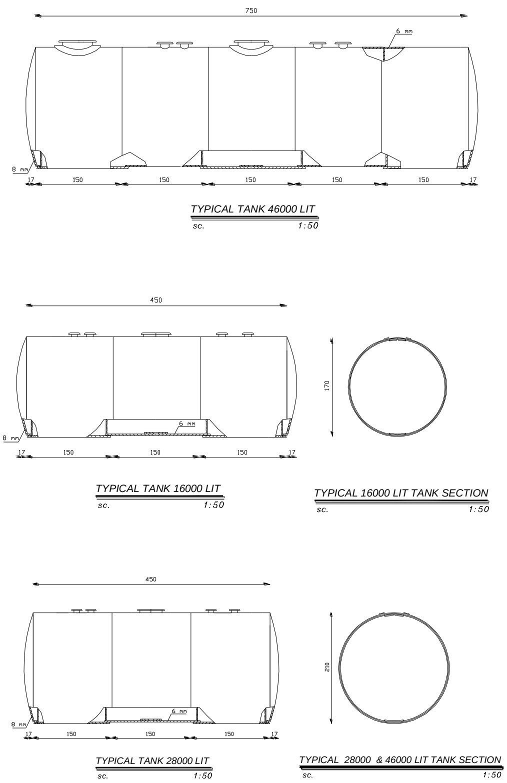


Figure 3. As built drawings of fuel tanks

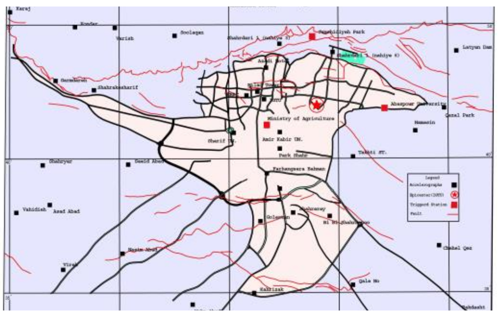


Figure 1. Location and seismicity of Tehran

Figure2. Picture of a station under investigations

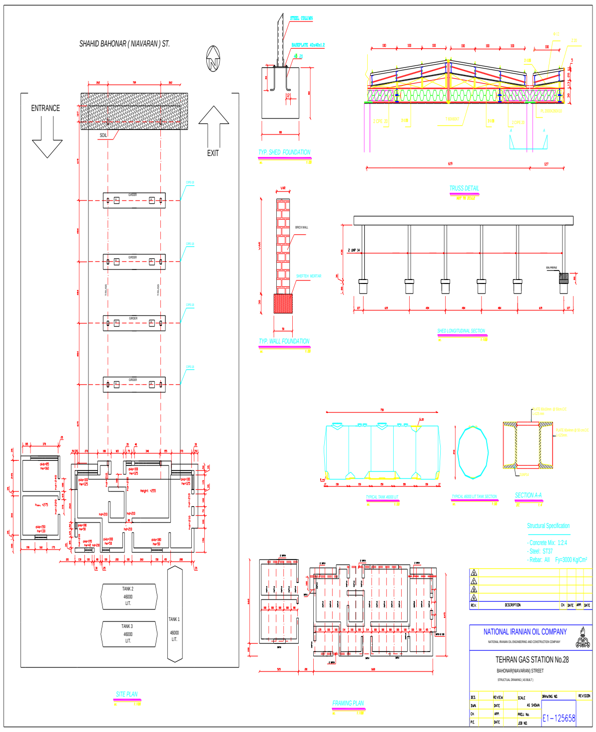


Figure 4. As built drawings of typical building and shed structures of a gas station under investigation

TABLE 1. Analysis of masonry buildings, walls in both directions

Base shear

A	I	W (ton)	V=0.33*A*I*W (ton)
0.47	1	123	19.08

lateral streghth of walls-Longitudinal

Direction	Story	Awi (m²)	Vi (ton)	Va=Vi/Aw (kg/cm²)	sc (kg/cm²)	Vt (kg/cm²)	Va(Allow)=0.1 Vt + 0.15 s (kg/cm²)	Va<=Va(Allow) (kg/cm²)
Long.	1	9.93	19.08	0.19	1.12	3	0.47	O.K

Atereal streghth of walls-Transuvere ((a) in-plane)

Direction	Story	Awi (m²)	Vi (ton)	Va=Vi/Aw (kg/cm²)	sc (kg/cm²)	Vt (kg/cm²)	Va(Allow)=0.1 Vt + 0.15 sc (kg/cm²)	Va<=Va(Allow) (kg/cm²)
Trans.	1	7.85	19.08	0.24	0.094	3	0.31	O.K

(b) out of plane

Wall Type	A	I	b (cm)	h (cm)	l (cm)	Ws (kg/m²)	Wp (ton)	Fp=0.7*A*I*Wp (ton)	S=L*b²/6 (cm³)	M=Fp.h/2 (ton.m)	□=M/S (kg/cm²)	fm (kg/cm²)	ft=.15*fm (kg/cm²)	check (□<ft)
8	0.47	1.0	40	255	100	720	1.84	0.60	26666.67	0.77	2.89	25.00	3.75	O.K
7	0.47	1.0	35	255	100	700	1.79	0.59	20416.67	0.75	3.67	25.00	3.75	O.K
6	0.47	1.0	35	255	100	670	1.71	0.56	20416.67	0.72	3.51	25.00	3.75	O.K
4	0.47	1.0	30	255	100	570	1.45	0.48	15000.00	0.61	4.06	25.00	3.75	N.G
3	0.47	1.0	30	255	100	530	1.35	0.44	15000.00	0.57	3.78	25.00	3.75	N.G

3. 2. Shed Structure Shed structure was analysis by the use of ETABS software. Structural elements were analyzed for load combinations sanctioned by the Iranian seismic provisions for capacity to demand ratios were used for evaluations based on the ratios, weak links were identified as shown in the figure.

3. 3. Pumps Pumps were analyzed for the loads mandated by the Iranian seismic code. As seen in Figures 5 and 6, overturning and sliding of pumps were also controlled. As shown, pumps in general created no seismic threat.

3. 4. Fuel Storage Tanks Just about all of the tanks were stored in the ground. Through piping, fuel was transferred to the pumps. Three different finite element models were considered as shown in Figure 7. As shown by the calculations, in any case, fuel tanks did not cause concern. Also, due to corrosion, a minimum thickness of 8 mm was calculated for different size of tanks as safe operation thickness. Maximum stress is shown in Table 2.

3. 5. Piping Due to restricted piping regulations used by the Oil Company, no significant hazard was realized during inspections. All pips were embedded on lose sand and encased by more than 2 inches of sand, around, for flexible behavior. Only problem encountered was the joint where the piping from the tanks connected to the main pips. A flexible connection was devised for better and ductile behavior as shown in Figure 8. Electrical lines and switches were all installed on the walls from the outside by flexible attachments; therefore no significant hazard was associated with them.

Figure 5. A typical pump used in gas stations in Tehran

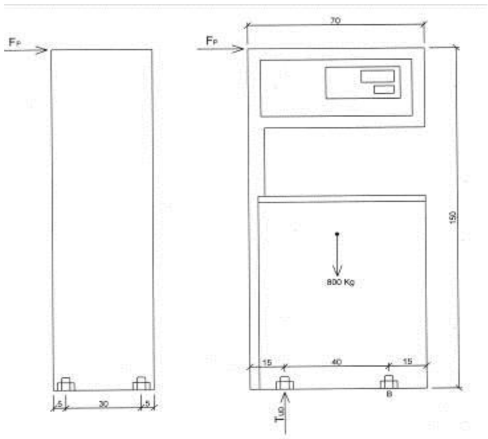


Figure 6. Free body diagram of pumps

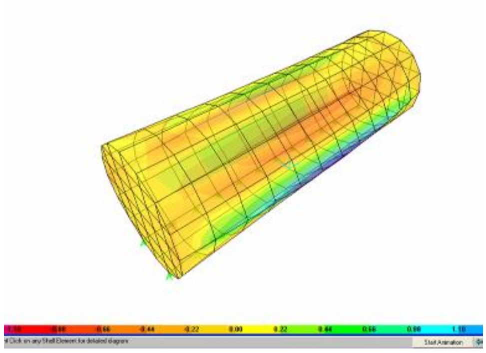


Figure 7. Model considered for the fuel storage tanks

TABLE 2. Typical maximum stresses for 47000 liter tank

TK-47000 combination X					
S11 Top	S22 Top	S12 Top	S11 Bot	S22 Bot	S12 Bot
kg_f/cm^2	kg_f/cm^2	kg_f/cm^2	kg_f/cm^2	kg_f/cm^2	kg_f/cm^2
2100	1744	361	1116	1449	456
TK-47000 combination Y					
S11 Top	S22 Top	S12 Top	S11 Bot	S22 Bot	S12 Bot
kg_f/cm^2	kg_f/cm^2	kg_f/cm^2	kg_f/cm^2	kg_f/cm^2	kg_f/cm^2
2103	1749	354	1118	1453	451

4. STRENGTHENING TECHNIQUES USED

Different schemes were used for strengthening different sections. For masonry buildings, main attempt was to create a structural system with providing a grid of steel sections joint with proper connections in between walls and by welding roof beams and joist to these newly framed steels. In framed buildings, addition of bracing and welding of new sections to existing ones were the main retrofitting philosophy used.

For pumps, pips and tanks no upgrading recommendations were considered. It was suggested that if after NDT tests of tanks for possible corrosions, the thicknesses were less than the ones suggested for the safe operation by this study, it would be wise to replace the tank totally. This would be of course much economical and trying to do some alterations.

For shed structure which almost all were vulnerable, depending on type of structure, use of new and stronger connections and addition of steel plates to columns while strengthening foundations were proposed as shown in Figure 9. Figures 10 and 11 show pictures of strengthening construction used in one such station. Figure 12 showes a typicak Strengtheeing sheet for typical gas station.

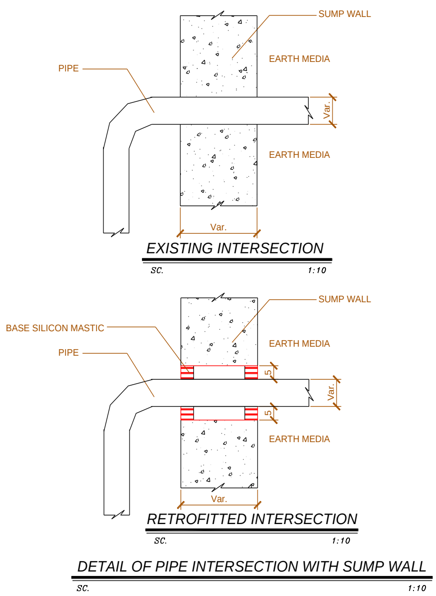
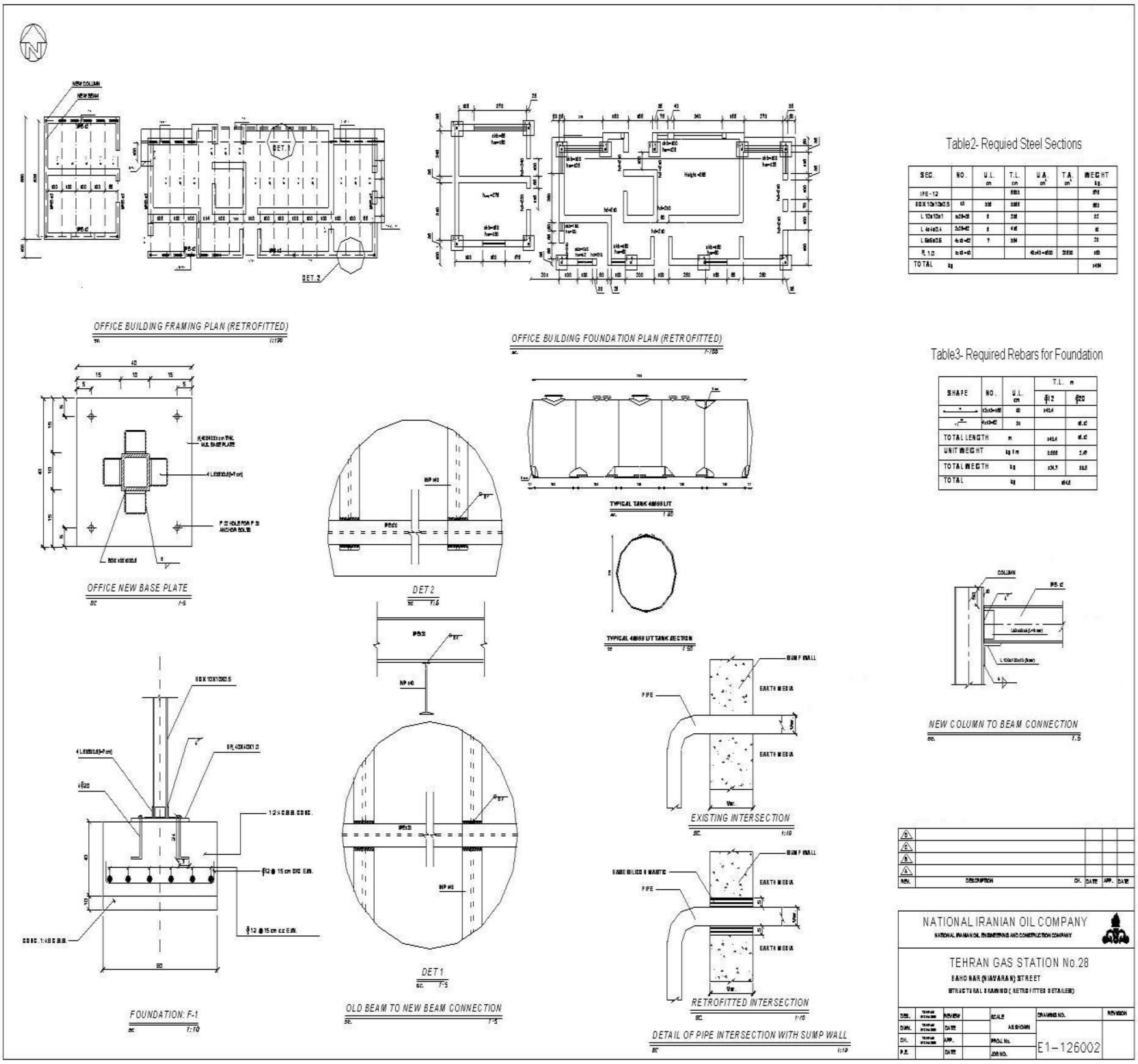


Figure 8. Ductile connection between tank and main piping system

Figure 9. Photo of Foundation Retrofitting

Figure 10. Photo of strengthening construction in a gas station in Tehran

Figure 11. Photo of strengthening construction of a gas station in city of Tehran



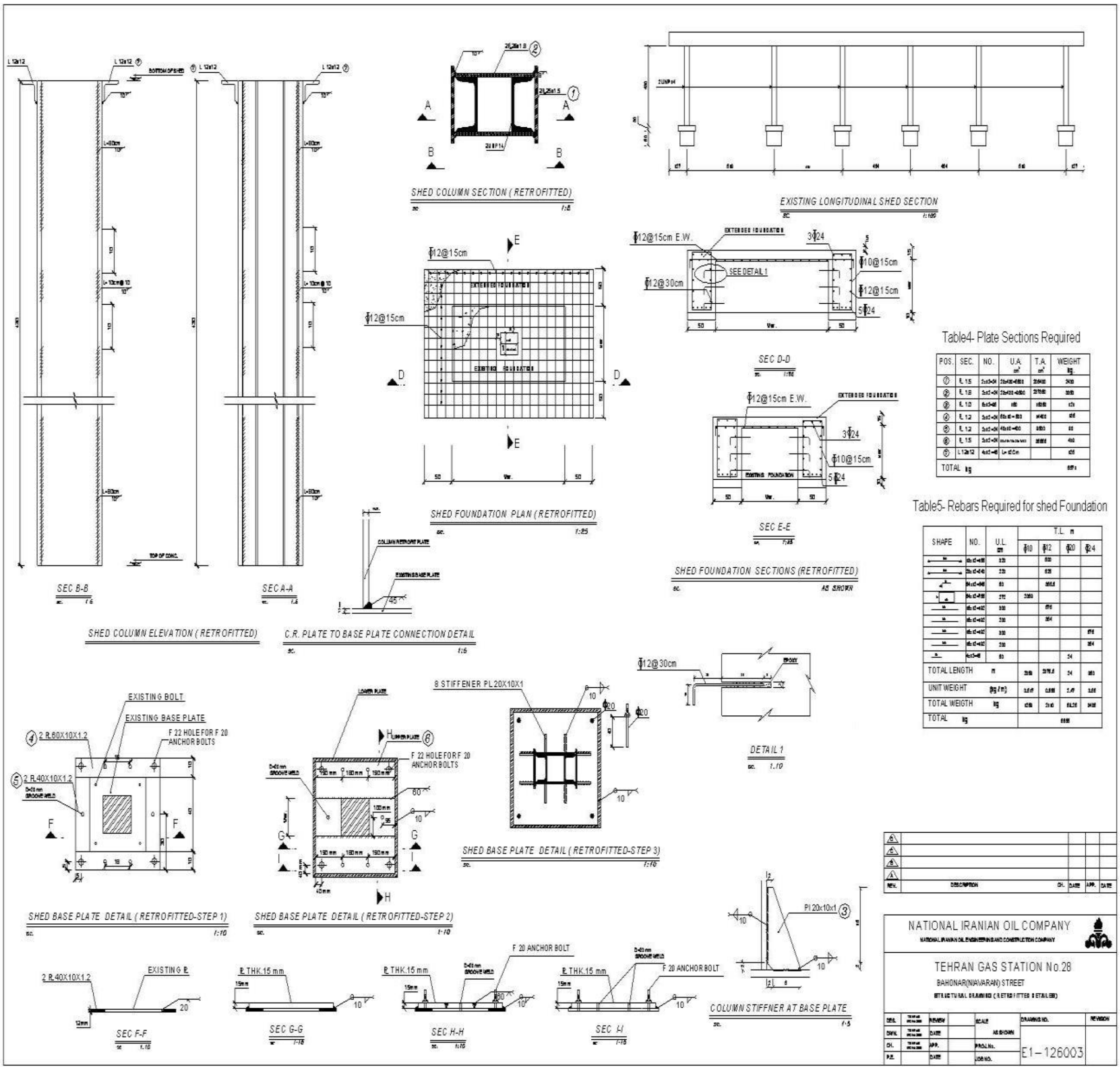


Figure 12. Strengthening schemes used for a typical gas station

5. CONCLUSIONS

In this study, 153 gas stations in city of Tehran were investigated for seismic vulnerability. In many cases, buildings and sheds were weak and needed strengthening which were designed for.

Pumps, tanks and piping needed no seismic considerations since they were designed and constructed in accordance to more restricted codes. Retrofitting has begun and it is believed upon completions, relatively safer fuel continuity will be guarantied in case of an earthquake in city of Tehran.

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, Acknowledge their support.

7. REFERENCES

1. Nateghi, F., “Interim Report on the Evaluation of 153 Gas Stations in City of Tehran”, ***Ministry of Oil, Tehran, Iran***, Vol. 21, (2008)
2. Nateghi, F. , “Final Report and Retrofitting Drawings of Gas Station in Tehran”, Refinery and Distribution, ***Ministry of Oil, Tehran, Iran,*** Vol. 153,.(2015)

Seismic Evaluation and Retrofit of Gas Stations: Case Study

F. Nateghi-A., A. Rezaie Tabrizi and M. khazaei Poul

University of Wisconsin–Madison, USA and former IIEES Graduate student, Tehran, Iran
Drexel University, Pennsylvania, USA and former IIEES Graduate student, Tehran, Iran

P A P E R I N F O

Paper history:
Received 22 November 2015
Received in revised form 16 January 2016
Accepted 26 January 2016

Keywords:
Retrofit
Gas Stations
Seismic Evaluation
Equipments
Pumps
Tanks

چکیده

ایران کشوری است لرزه‌خیز و پایتخت آن تهران دارای ۱۵۳ پمپ‌بنزین می‌باشد که عموماً در بناهای غیر مقاوم بناشده‌اند. برای ارزیابی و مقاوم‌سازی این تعداد از پمپ‌بنزین‌ها در وزارت نفت طی پروژه‌ای که شامل بررسی ساختگاه، آسیب‌پذیری ساختمان‌ها، پمپ‌ها و مخازن و سپس ارائه روش‌های مقاوم‌سازی بود تعریف‌شده که در این مطالعه ریز این مطالعات و نحوه ارزیابی لرزه‌ای و مقاوم‌سازی آن ارائه می‌گردد. ابتدا خطر به‌صورت تهیه نقشه خطرپذیری و سپس مطالعات تئوریک به‌صورت مدل‌سازی اجزاء محدود و درنهایت روش‌های مقاوم‌سازی مقرون‌به‌صرفه ارائه گردید.

***doi**: 10.5829/idosi.ije.2016.29.02b.06*