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QUALATATIVE AND QUANTATIVE SEISMIC EVALUATION OF REINFORCED CONCRETE STRUCTURES IN PETROCHEMICAL PLANT

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In this paper the seismic evaluation of reinforced concrete structures in petrochemical facilities under sever conditions such as high pressure, high temperature and corrosive environment is studied. These structures were designed and constructed during 1976-78. The evaluation procedure is basically performed in two phases namely; a) qualitative and b) quantitative methods. In the qualitative evaluation, all possible documentations including drawings, specifications, structural calculations, new additions and test results were studied. Collected data then was summarized in an evaluation checklist. When the needed requirements did not meet the specified entries, more detailed and quantitative analysis were performed and utilized in this study. Quantitative and numerical study was performed using finite element modeling under sever loading combinations. Based on the results of this evaluation, some important RC structures in this plant were highly vulnerable to seismic forces which required immediate attention. The methodology used and results obtained can be generalized and adapted for similar facilities. This paper will present details, procedure and conclusions obtained.

Keywords: qualatative and quantative evaluation, reinforced concrete structure, petrochemical plant

1. Introduction

Iran is a country located on intersections of three major tectonic plates. Constant threat of major earthquakes from one side and aging buildings and industrial plants with no or very minor

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attention to seismic forces from other hand has created and ideal environment for researchers and engineers to use different methods in order to evaluate the seismic behavior of such structures.

In this regards, Shiraz petrochemical facilities was selected for one such study. Shiraz Petrochemical plant is located at southern province of Fars along the foothills of Zagros mountain ranges. This section of Iran has a very high seismicity and has experienced many devastating earthquakes through out the history. Figure-1 shows the location of this petrochemical plant. Figure-2 indicates the seismicity and the zonation of the facilities in the region. This plant consists of many different units namely; ammoniac, ammonium nitrate, nitric acid, urea, power plant, water treatment, cooling and sulfur processing unit.

Building structures at the plant were of R/C or steel framed constructions. These structures were designed and constructed by English and Dutch companies during 1976 to 1978. Seismic loading of structures were based on UBC while seismic design was performed based on BS code. In order to check and upgrade the design to newer versions of codes, and also to account for the deficiencies in BS regarding seismic provisions, R/C structures were subjected to vulnerability studies. The evaluation procedure is basically performed in two phases namely; a) qualitative and b) quantitative methods. In the qualitative evaluation, all possible documentations including drawings, specifications, structural calculations, new additions and test results were studied. Collected data then was summarized in an evaluation checklist. When the needed requirements did not meet the specified entries, more detailed and quantitative analysis were performed and utilized in this study.

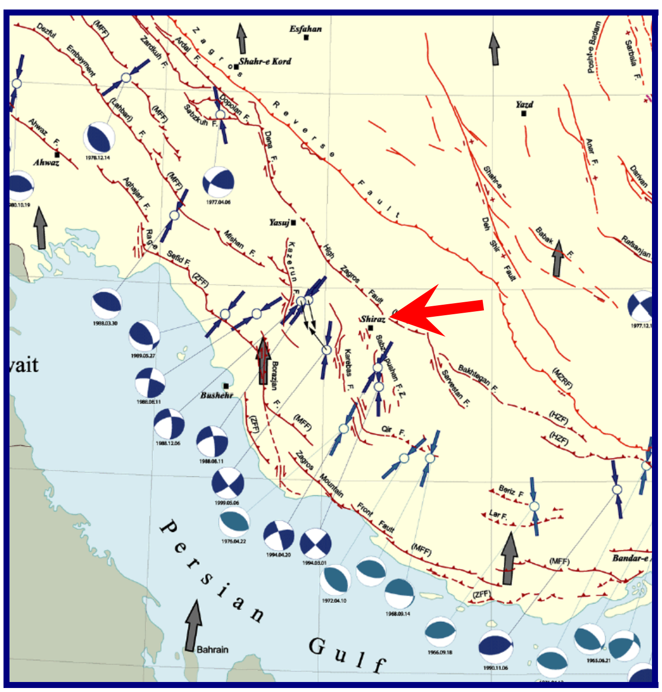

Figure 1. Location map of Shiraz

Quantitative and numerical study was performed using finite element modeling under sever loading combinations. Based on the results of this evaluation, some important RC structures in this plant were highly vulnerable to seismic forces which required immediate attention. The methodology used and results obtained can be generalized and adapted for similar facilities. This paper will present details, procedure and conclusions obtained.

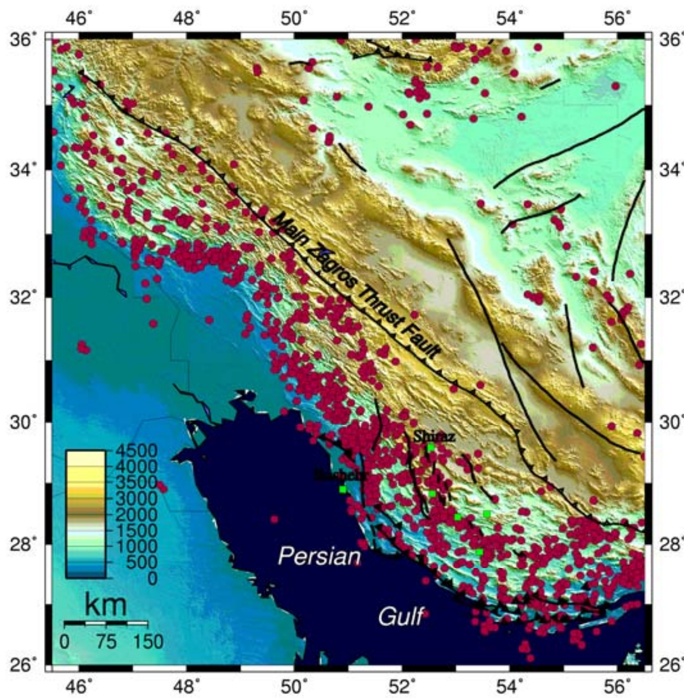

Figure 2. Seismic zonation and seismicity of region

2. Perdominant Modes of Concern in Seismic Study of Reinforced Concrete Structures

The most important issues in seismic vulnerability assessment of R/C structures which were considered in this study are summarized as follows: (a) Existence of strong beam-column; (b) Shear weakness in beams; (c) Column joints; (d) Not enough stirrups in beams and columns; (e) Eccentricity in beam to column connections; (f) Corrosion; (g) Interaction between adjacent structures and equipments; (h) Large openings in diaphragms; (i) Degradation of concrete materials; (j) Short column; (k) Use of flat slabs; (m) Discontinued reinforcements or cut reinforcements.

Some of these problems are shown in Figures-3a to 10 (Nateghi-A, Rezaei Tabrizi, Hossein zadeh, 2003). These photos indicate the existing structures having above mentioned cases.

Figure 3. Photo of possible torsion condition

Figure 4. Cracks and degradation of R/C members

Figure 5. Absence of beam to column connection

Figure 6. Corrosion due to chemical compounds

Figure 7. Strong beam, Weak column in both sides of structure

Figure 8. Nonsymmetrical non-Structural contribution in height and plan

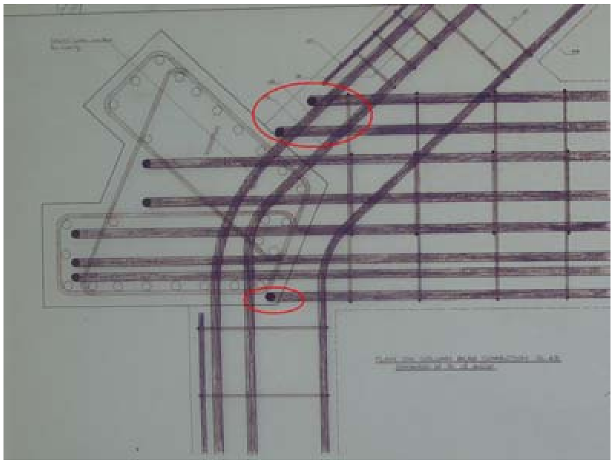

Figure 9. Undesirable anchorage of steel and reinforcement and R/C Bars not continued in beam column Joint

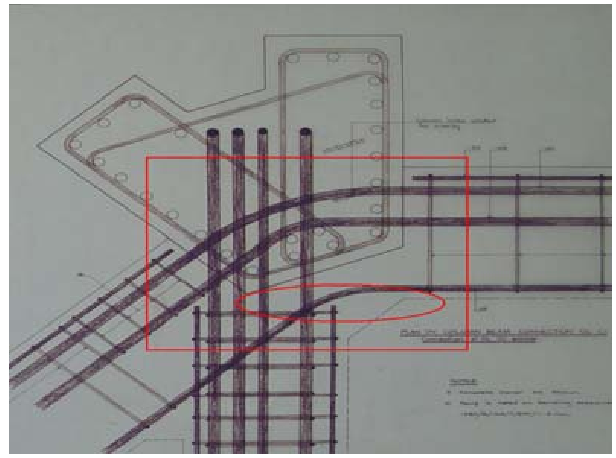

Figure 10. Weakness of beam-to-column Joint, few shear reinforcements and eccentricity of beam to column connection

3. Seismic Evaluation

Seismic Evaluation of Buildings was performed in two phases namely; Qualitative and Quantitative. Standards used for this study were, ACI-318-99, ATC-14, Iranian 2800 Seismic Provisions and ASCE. Each procedure is defined as follows;

3.1. Qualitative Method

For the Walk down survey of existing structures, first a checklist for structural and non-structural elements was designed. The checklist was based on combination of recommendations by ATC-14, ASCE and Iranian code. In this survey form, general questions as well as specific data regarding each structure and components were collected. A wall down of each specific structure was performed and checklist was filled out creating a data bank. All existing documents and drawings including the results of NDT tests performed in the past were also investigated. Photos were taken from each item such as bad construction, degradation, lack of bolts, misplaced reinforcement, corrosion and other related qualitative items. Figure-11 shows the flow chart used for this section of the study while Figure-12 indicates the form used and questions collected.

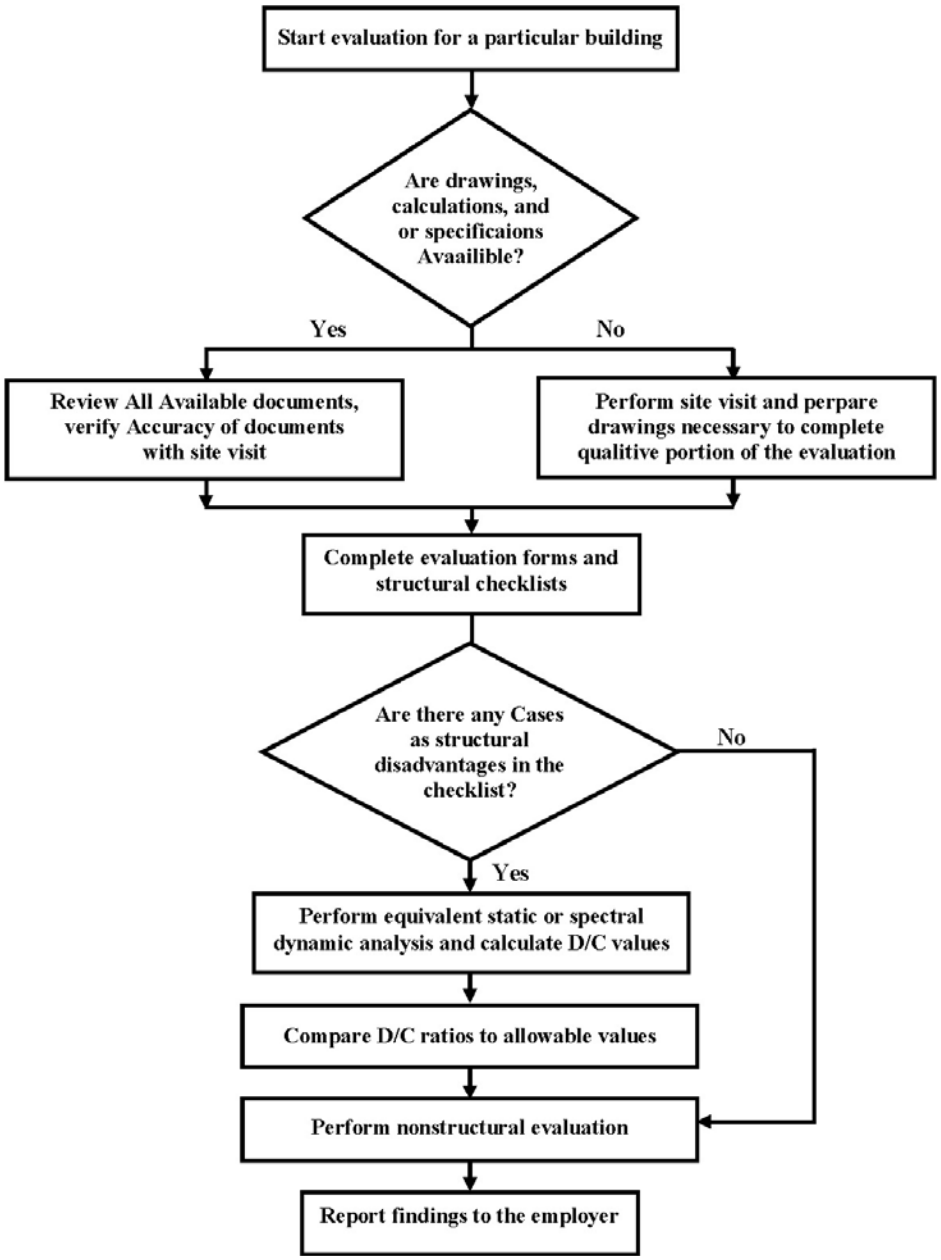

Figure 11. Flow chart used for walk down survey

3.2. Qualitative Method

Based on the results obtained by the visual screening, ETABS-2000 was used to model the structures. For modeling purposes frame elements were used for columns and beams whereas shell element was considered for shear walls, diaphragms and spandrels. Trial and error was done for the determination of optimum size of shell elements until convergence of analysis outputs including displacements and internal forces. Dynamic spectral analysis was done with the assumption of linear elastic behavior for materials and use of site specific response spectrum.

Base shear from spectral analysis was normalized to the value obtained from the static equivalent procedures. Modeling of structures were done in 3D form, while the number of dynamic modes used in analysis was determined based on achievement of 90% seismic structural mass. ACI-318-99 was used for the control of structural sections and calculations of C/D (capacity to demand) values. Finally, vulnerability of structures were determined by comparisons of the calculated C/D's with the allowable C/D values obtained from ATC-14. Criteria used are as follow: C/D < 1.1 safe, 1.1 < C/D < 1.2 vulnerable, C/D > 1.2 very vulnerable. Figures-13 to 15 show some of the results obtained in different buildings. Table-1 also indicates the resulted vulnerabilities at the site for different existing R/C structures [Nateghi-A, Rezaei Tabrizi, Hosseinzadeh, 2003].

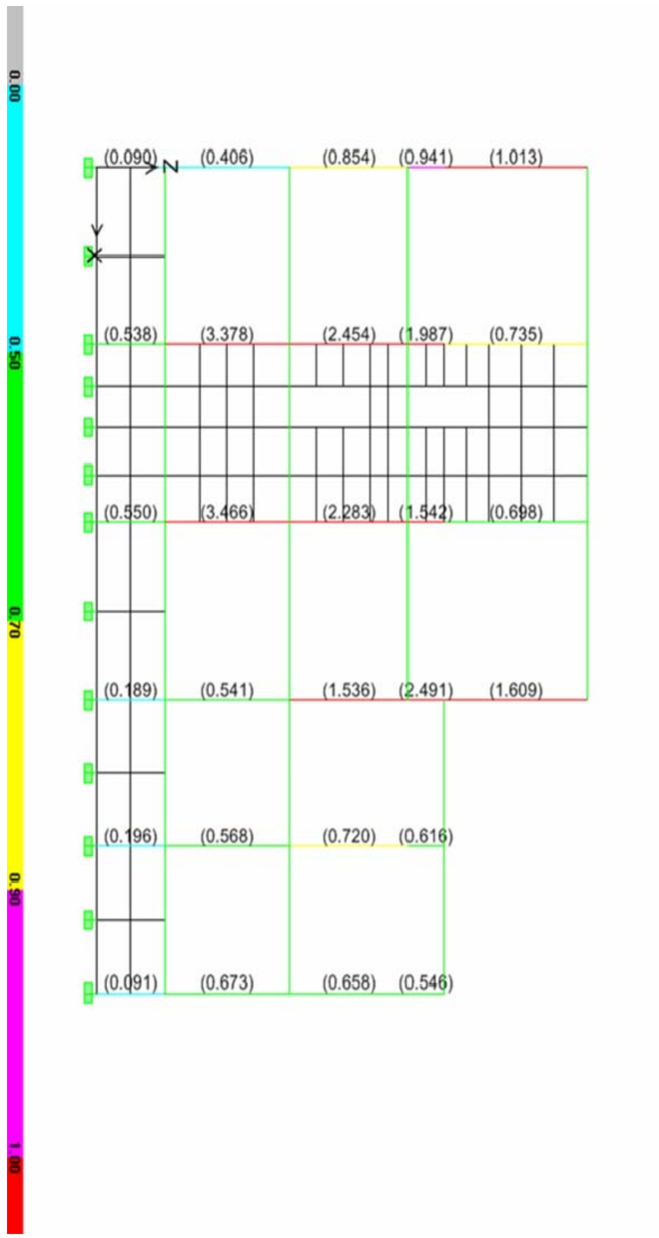

Figure 12. Critical D/C values for beams and columns in the sample frame of the Lime Dosing Building

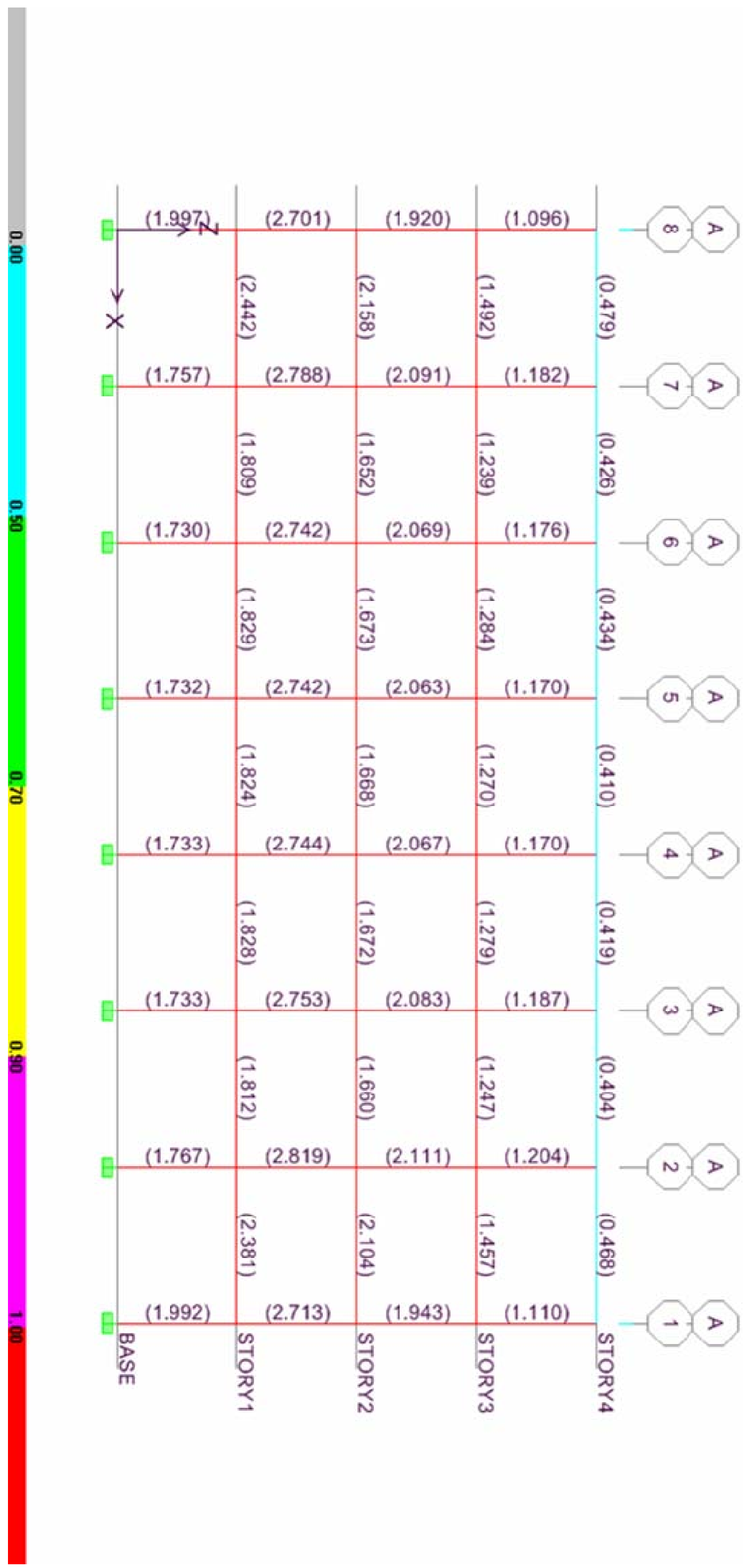

Figure 13. Critical D/C values for beams and columns in the sample frame of Administration Building

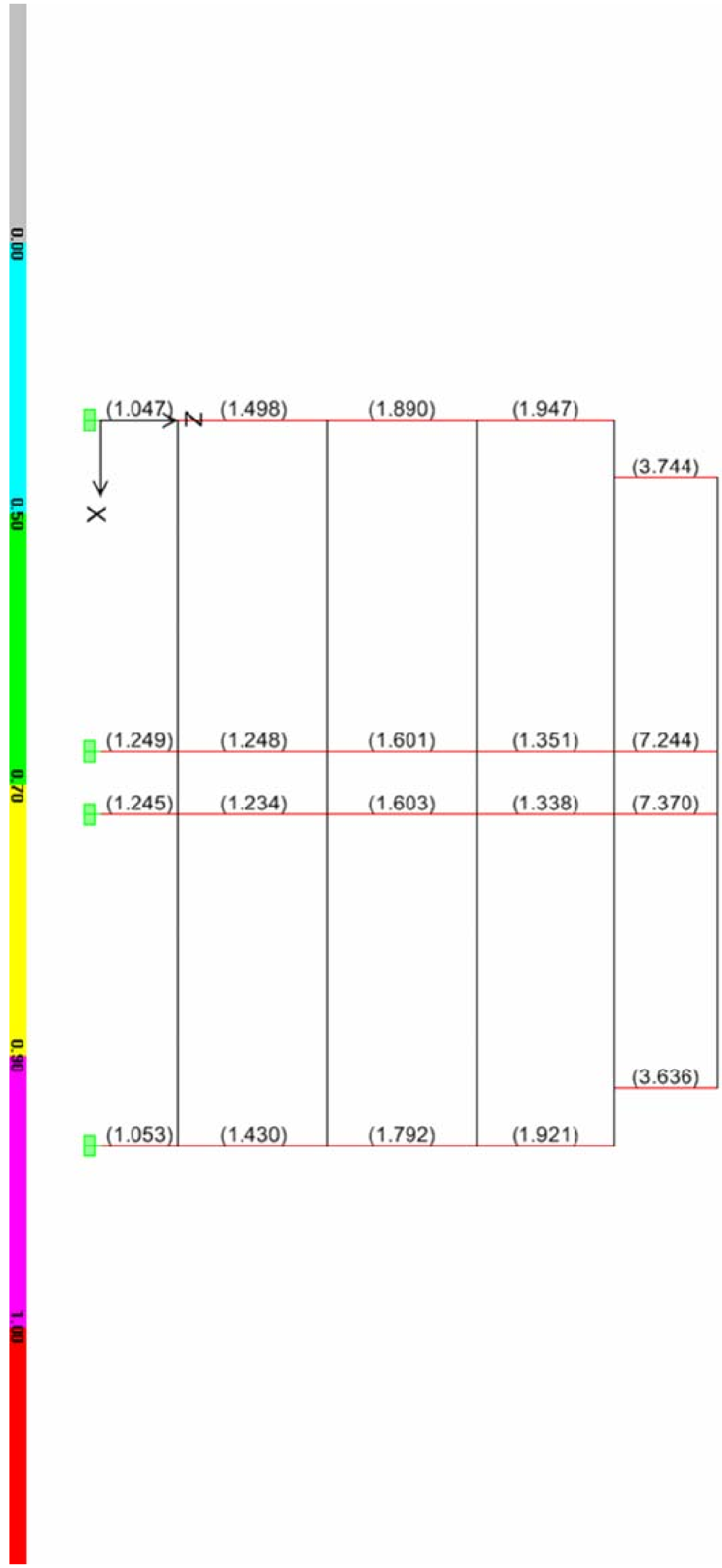

Figure 14. Critical D/C values for beams and columns in the sample frame of the Main Control Building

Table 1. Seismic evaluation of existing R/C structures in Shiraz Petrochemical Plants

Structure Name	Valnerability Situation
Administration building	very valnerable
Lime dosing building	very valnerable
Control building	very valnerable
Sub station buildings	very valnerable
One story buildings	vulnerable

4. Conclusions

Two parts techniques were used in order to evaluate the structure in a petrochemical plant under sever conditions namely walk down survey and analytical calculations. Both methods in conjunction of each other indicated sever weak links in the structures. Based on the study of the Shiraz petrochemical facilities, the existing R/C structures which is very important for the after earthquake scenario, posses major vulnerabilities. This evaluation indicates that the management of the plants should seriously consider the upgrading of these specified buildings to at least current operational codes.

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