Seismic Safety Assessment Tools for Suburban Building Stocks

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ABSTRACT: In this study, current assessment techniques are discussed. Assessment procedures are classified as pre-earthquake and post-earthquake methods. Pre-earthquake assessments are performed with different level of accuracy depending on both the available resources and required results. Preliminary evaluation methods such as P25 or ASCE 31-03 Tier 2 – Evaluation Phase methods are suggested to use in the "Improving the Quality of Suburban Building Stocks" project.

1 INTRODUCTION

The project entitled "Improving the Quality of Suburban Building Stocks" states that European postwar multi-family housing stocks must comply with current requirements for seismic performance. Besides aesthetics, functionality, sustainability and energy efficiency, if the structures are located in seismic areas, safety of these buildings against seismic activities must be assessed during the refurbishment or renovation program. The results of such assessments are essential for rational planning of the program for existing buildings before the occurrence of a strong earthquake.

It is notable to mention that in many strong earthquakes older postwar multi-family housing structures may cause much more casualties and damages than new structures. Because, in most seismic regions of the world, older buildings, originally built with inadequate seismic resistance, constitute by far the largest risk of economic and life safety losses (Holmes, 1996). Therefore, during the refurbishment process, the assessment of the seismic capacity of existing structures and prioritization for strengthening must be evaluated.

Assessment procedures can be classified as pre-earthquake and post-earthquake methods. Pre-earthquake assessment can be performed with many levels and for many different purposes, ranging from estimates of probable loss to inventories by insurance companies, to classification of risk by building classes, to detailed analysis of single buildings (Holmes, 1996). The main interest of post-earthquake evaluation is the safety of buildings against further shocks. Since citizens are not usually able to evaluate the residual building strength and as the number of buildings to be inspected is very huge, safety inspections are usually managed by proper institutions. Inspectors have to balance the safety of citizens, since once the building is judged safe, people will keep living there, against the need to reduce peoples' discomfort. Often associated to the safety assessment is the evaluation of the short term countermeasures necessary to guarantee private and public safety (LESSLOSS 2007/2). In this study pre-earthquake assessment phases will be discussed.

2 PRE-EARTHQUAKE ASSESSMENT PROCEDURES

Over the last two decades, in order to minimize the economic losses due to moderate to large earthquakes, a number of assessment procedures have been proposed in the literature. Pre-earthquake assessment methods, depending on both the available resources and the required results, have three different applications (Figure 1).

2.1 *Rapid Visual Screening Methods*

For large-scale (national) applications, the acquisition and analysis methodologies must be compatible with a little amount of data, and the swiftness of the procedures is an indispensable requirement (Level 1). The Level 1 assessment procedures are the simplest and quickest way, called walk-down survey or street survey, requires only superficial data collected from a brief inspection of the building. The number of stories, vertical and plan irregularities, location of the building, age of the building, its structural system and apparent material and workmanship quality are typical parameters that are used. FEMA 154 (the rapid visual screening procedure -RVS), FEMA 310 Tier 1 and ASCE 31-03 (Tier 1- Screening Phase) evaluation methods fall into this category (Figure 1). The purpose of rapid assessment techniques is to identify or rank highly vulnerable buildings that deserve further investigation (Yakut, 2004). Generally, the level of knowledge required for this application is consistent with data retrieved from national censuses (occupation type, location, year of construction, structure type, number of floors, and number of dwelling units) (LESSLOSS 2007/2).

Another Level 1 assessment procedure named as Seismic Safety Screening Method (SSSM), have proposed by Ozdemir et al.(2004) which is an adaptation of the Japanese Seismic Index Method (JSIM) considering the building damages in recent earthquakes of 1992 Erzincan, 1998 Adana-Ceyhan, 1999 Marmara and Duzce, 2003 Bingol and 2005 Karliova Earthquakes. The original method have been applied to a number of buildings damaged during 1992 Erzincan, 1998 Adana-Ceyhan and 1999 Marmara and Duzce Earthquakes. These results have been used for adaptation of the original method to Turkey. This rapid seismic safety evaluation method can be applied for structures having a storey number 6 or less with reinforced concrete frame, shear wall or dual frame-shear wall structural systems. The calibration of several coefficients proposed in this method will further be done considering the studies carried out in various pilot areas like Zeytinburnu-İstanbul (LESSLOSS 2007/04).

2.2 *Preliminary Assessment Methods*

For medium-scale (regional) applications, the acquisition and analysis methodologies can be supported by a more consistent amount of data and procedures can be more refined, even if still simple (Level 2) (LESSLOSS 2007/04). When a more detailed and reliable assessment is needed, then preliminary assessment techniques are employed. In addition to what is collected from the street survey, data on the size and orientation of the structural components, material properties and layout are needed. This requires entry to the building and review of drawings. This procedure does not rely on sophisticated and time-consuming analysis of the building but some quick calculations are performed. The structural capacity is usually expressed in terms of an index, which is checked against an anticipated demand. By this comparison, the expected performance of the building is predicted. The success of these techniques depends on the availability and quality of data (Yakut, 2004). ASCE 31-03 (Tier 2- Evaluation Phase) evaluation is a widely used preliminary assessment technique (Figure 1).

An alternative preliminary assessment method named as P25-v2 was initially suggested by Bal (2005) and then developed and calibrated through a research project supported by TUBITAK (Turkish Scientific and Technical Research Council, Project No: 106M278, 2006). When it was applied to 311 RC buildings with different damage states subjected to various seismic actions and located on different soil conditions, very promising results were obtained (Bal et al., 2007). The name of the method refers to the 25 different structural features of the investigated buildings which are either measured or observed visually and then the building performance score is determined by means of simple calculations. P25-v2 Method is primarily based on calculation of ratios related to cross-sectional characteristics of structural members and infill walls, as well as on observing and scoring the most important structural parameters which affect the seismic response of buildings. The basic parameters of the methodology may be listed as: (a) cross-sectional dimensions of RC columns, shear-walls, and infill walls at the critical floor, which is usually the basement or ground floor; (b) story heights and the total height; (c) outer plan dimensions of ground floor; (d) typical beam dimensions; (e) effective ground acceleration; (f) building importance factor; (g) soil conditions and soil profile and; (h) other observational or measurable parameters like material quality, confinement zones of columns, pounding effect, topographic conditions, various structural irregularities such as, short columns, torsion, soft story, frame discontinuity, etc (Gulay, 2008).

An improved procedure was proposed by Yakut (2004) for assessing preliminary seismic vulnerability of reinforced concrete buildings having moderate ductility. The procedure relies on the orientation, size and concrete strength of vertical load resisting components. It accounts for the contribution of effective filler wall areas, and reflects the influence of architectural features, taking into account the negative effect of poor construction quality

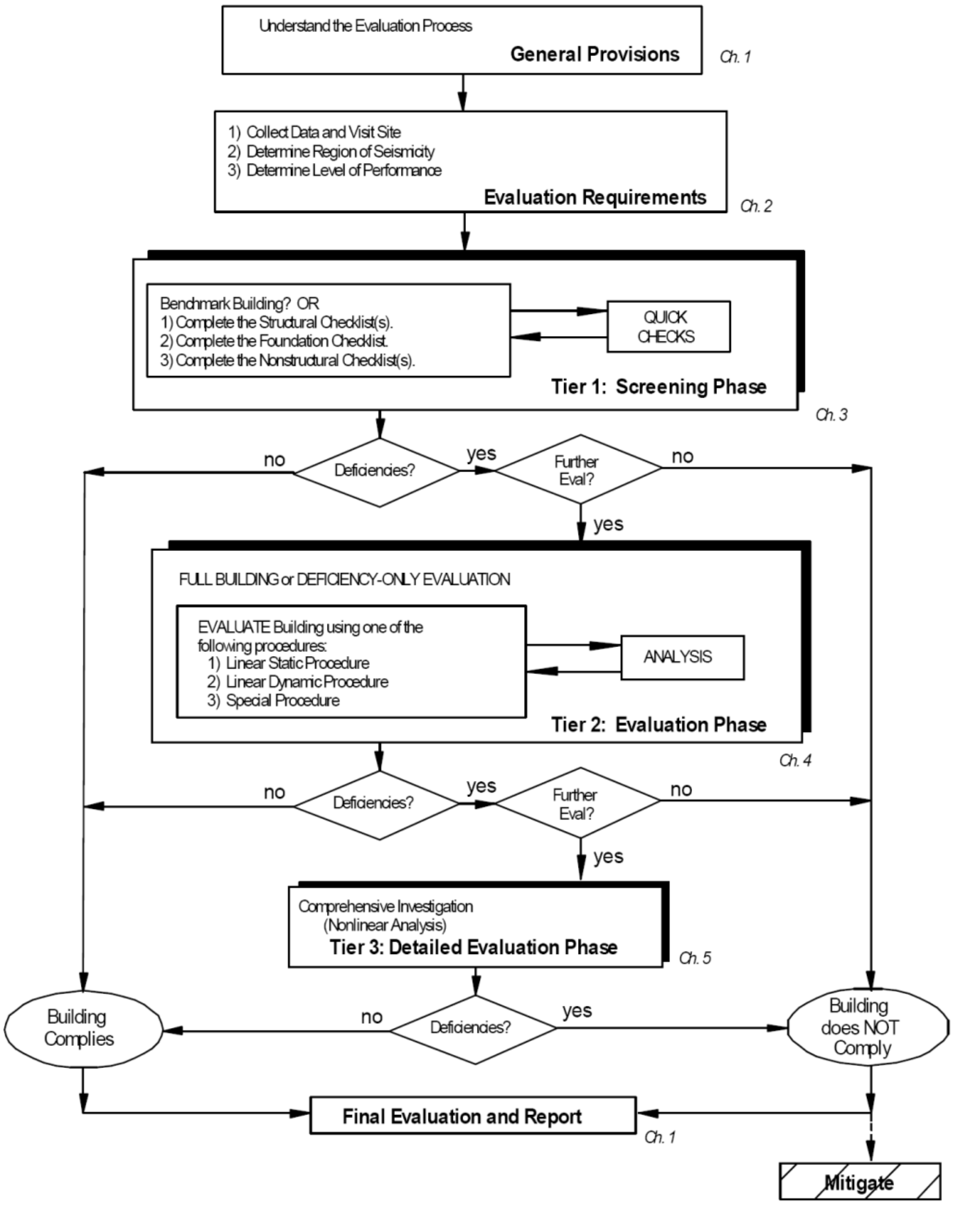

Figure 1. Evaluation Process of FEMA 310.

2.3 *Detailed Evaluation Methods*

For small-scale (local) applications, the acquisition and analysis methodologies must be very accurate because single objects (a single bridge, or building) are considered (Level 3) (LESSLOSS 2007/02). The in-depth evaluation of the buildings through sophisticated structural analyses falls into the third category of vulnerability assessment. The comprehensive information on the geometrical properties of the components, mechanical properties of the materials, and detailing of the components are obtained from the structural drawings and as-built features of the building. Linear or non-linear analysis techniques are used to determine the response quantities for an anticipated seismic action. These response quantities are then compared with certain accepted values to arrive at a decision regarding the expected performance of the building. FEMA 356, ATC-40, FEMA 310 Tier 3, ASCE 31-03 (Tier 3- Detailed Evaluation Phase) and Japanese level three (Ohkubo, 1991) evaluation procedures are among the most widely used techniques at this level. This level of assessment is generally used in site specific applications, and is able to capture architectural features, material quality as well as detailing of the components to a certain extent. Among three assessment phases, the preliminary evaluation is the most widely used technique when a reliable and quick assessment is needed (Yakut 2004).

The most notable document available for seismic evaluation of existing buildings is ASCE 31- 03: Seismic Evaluation of Existing Buildings (ASCE, 2003), originally derived from FEMA 310: Handbook for the Seismic Evaluation of Existing Buildings – A Prestandard (FEMA, 1998). FEMA 310 was converted to ASCE 31 as part of the American Society of Civil Engineers standardization process. ASCE 31-03 is intended for use on older building and recognizes that older and out-moded structural systems may be incorporated in these buildings. The seismic life safety provided by a building is judged adequate if the requirements are met and many jurisdictions accept this level of performance for their community (FEMA 547).

3 CONCLUSIONS

All of the existing assessment methods based on the statistics of past EQ damage observations. Level 1 method is based on expert's subjective opinion and has limited reliability. Level 2 methods are based on simple analytical methods to simulate buildings response that are essentially simple approximate solutions that must rely on a few parameters. On the other hand, Level 3 methods are more accurate but require much data and are time-consuming.

For the seismic safety assessment of the suburban housing stocks, medium-scale application is considered as appropriate starting point. In this level, P25-v2 preliminary assessment method seems a very promising procedure to find out and eliminate quickly the collapse vulnerable buildings. In case where some of the buildings are classified within the high risk band, level 3 methods are specifically employed to assess the structure in detail by expert engineers.

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