A rapid analysis method for determining current status of existing buildings: A conceptual framework

Un método de análisis rápido, para determinar el estado actual de los edificios existentes: Un marco conceptual

Baris Yildizlar (Main and corresponding author)
Istanbul University-Cerrahpasa, Department of Civil Engineering
Istanbul, Turkey
peace@istanbul.edu.tr

Cemil Akcay
Istanbul University-Cerrahpasa, Department of Civil Engineering
Istanbul, Turkey
cakcay@istanbul.edu.tr

Namik Kemal Öztorun
Istanbul University-Cerrahpasa, Department of Civil Engineering
Istanbul, Turkey
kemal@istanbul.edu.tr

Manuscript Code: 955
Date of Acceptance/Reception: 17.07.2018/03.08.2017
DOI: 10.7764/RDLC.17.2.267

Abstract
Considering the loss of lives and economical loss arising out of earthquake motions, it becomes necessary to determine the safety levels and vulnerability of the existing buildings especially in the urbanized areas and to take due precautions. As a matter of fact, it is not convenient to determine the safety levels of a large number of structures by using the common analysis methods with respect to the temporal and economical aspects, because there are great numbers of structures, fewer expert engineers in proportion to number of structures, the said process is economically large-scaled, and it takes too long to determine the structural safety, as well as the fact that it is possible to determine the safety level of a structure by using many parameters. In order to determine the safety levels of structures, it is required to develop fast evaluation methods which are free from any subjective parameters and based on local specifications and compatible with production techniques and practices. In line with this purpose, it is necessary to carry out structural surveys to determine the safety levels of structures by using the parameters, which should be chosen in the minimum basis, but assuring the reliability criteria. The algorithm containing the minimum evaluation criteria, which are essential to evaluate the present condition of structures in accordance with the mathematical bases, and a quick evaluation method featuring the said algorithm are introduced in the presented study. The structural safety of many structures against earthquake effects has been determined fast and correctly by using the developed method.

Key words: Computer-based program, rapid estimation method, seismic effect, RC building, masonry building.

Resumen
Teniendo en cuenta la pérdida de vidas y las pérdidas económicas derivadas de los movimientos sísmicos, es necesario determinar los niveles de seguridad y la vulnerabilidad de los edificios existentes, especialmente en las zonas urbanizadas, y tomar las debidas precauciones. De hecho, no es conveniente determinar los niveles de seguridad de un gran número de estructuras utilizando los métodos de análisis comunes con respecto a los aspectos temporales y económicos, porque hay un gran número de estructuras, menos ingenieros expertos en proporción a número de estructuras, dicho proceso es económicamente de gran escala, y lleva demasiado tiempo determinar la seguridad estructural, así como también el hecho de que es posible determinar el nivel de seguridad de una estructura mediante el uso de muchos parámetros. Para determinar los niveles de seguridad de las estructuras, se requiere desarrollar métodos de evaluación rápidos que estén libres de parámetros subjetivos y basados en especificaciones locales y compatibles con las técnicas y prácticas de producción. De acuerdo con este propósito, es necesario llevar a cabo estudios estructurales para determinar los niveles de seguridad de las estructuras mediante el uso de parámetros, que deben elegirse sobre la base mínima, pero asegurando los criterios de fiabilidad. El algoritmo que contiene los criterios mínimos de evaluación, que son esenciales para evaluar la condición actual de las estructuras de acuerdo con las bases matemáticas, y un método de evaluación rápida que presenta dicho algoritmo se presentan en el estudio presentado. La seguridad estructural de muchas estructuras contra los efectos del terremoto se ha determinado rápida y correctamente mediante el uso del método desarrollado.

Palabras clave: Programa basado en computadora, método de estimación rápida, efecto sísmico, construcción RC, construcción de mampostería

Introduction

It is possible to say that the safety of any building can be defined by the effect of a wide range of parameters. The parameters include the seismicity of the structure where it is located, local soil properties, structure geometry, the properties of the section and material, location, the type of the bearing system, the connection details in all the structural members. Besides, determining the building behavior by only a few of the parameters or evaluating it by inadequate criteria might lead to incorrect results, detailing even one reinforcement might also directly affect the safety of the structure. While studying the structural safety of a building, determining the properties of the section and material of the structure with comprehensive tests, determining the positions of such invisible materials as reinforcements, deriving the earthquake characteristics and analyzing them in the light of the said information are agreed to be a method which is commonly known and applied. However, for such reasons as being time-consuming to apply the above method, the lack of the personnel, who are experts in their subjects, and the fact that there are thousands of structures to study, the developed methods are not convenient, which is why other similar methods, which give better results by using fewer parameters and within a short time, are needed. With regard to the methods, minimum parameters must be taken into consideration to determine the structural safety level, accuracy of the results must be determined and any probably errors must be minimized through correction coefficients. In this way, a need for mathematical model is a significant necessity in order to compare the buildings in accordance with the same principles relatively. The objective of this model should be elimination and minimization of perceptions, senses and feelings.

The study introduces a new method which is developed a computer program named as "DURTES" regarding rapid analysis of the buildings based on Turkish earthquake code (TEC-2007). In the scope of the above explanation, the proposed method named in this study have contributed to capability of rapid analysis method of existing structures.

State of the art

A number of researches have been carried out to investigate the rapid estimation methods. A poor performance of reinforced concrete (RC) frame buildings in India during past earthquakes has been a matter of serious concern. Hence, it becomes important to identify and strengthen the deficient buildings. When dealing with a large building stock, one needs evaluation methods for quick assessment of the seismic safety of existing buildings so that corrective retrofitting measures may be undertaken on the deficient buildings. This paper presents a review of some of the available methods for rapid visual screening (RVS) of RC-frame buildings and proposes a RVS method for RC-frame buildings in India based on systematic studies on damage data of the 2001 Bhuj earthquake (Jain, Mitra, Kumar, & Shah, 2010). An effective step for seismic risk mitigation in large urban areas under high seismic risk is to identify the most vulnerable buildings that may sustain significant damage during a future earthquake. Once they are identified properly, existing seismic risks may be reduced either by retrofitting such buildings, or by replacing them with new buildings in view of a particular risk-mitigation planning strategy. A fast and simple seismic risk-assessment procedure for vulnerable urban building stocks is proposed in this study. It is basically a sidewalk survey procedure based on observing selected building parameters from the street side, and calculating a performance score for determining the risk priorities for buildings. Statistical correlations have been obtained for measuring the sensitivity of damage to the assigned performance score by employing a database consisting of 454 damaged buildings surveyed after the 1999 Düzce earthquake in Turkey. The results revealed that the proposed screening procedure provides a simple but effective tool for selecting those buildings that have significant damage risk. These buildings have to be subjected to a more detailed assessment for a final decision on their seismic risk level (Sucuoğlu, Yazgan, & Yakut, 2007).

A risk prioritization procedure is developed for deficient concrete public buildings within the scope of a seismic risk reduction program. The main purpose is identifying public buildings with high damage risk in a region for efficient retrofit investments. Regularity of structural systems and repeatability of deficiencies in public buildings provide opportunities for developing simple and reliable assessment procedures. The proposed procedure is based on calculating a risk index from the comparison of lateral load demand to lateral load capacity at the critical story of a building, and then prioritize the buildings in accordance with their risk index. Final decision for retrofitting is made with reference to the ratio of retrofitting cost versus demolishing and rebuilding cost. It has been shown on a sample of 70 retrofitted public buildings that the retrofitting cost ratio of deficient buildings is independent of risk level, age, height, floor area and concrete quality (Sucuoğlu, Yakut, Özmen, & Kubin, 2015). Unreinforced and non-engineered masonry buildings are highly vulnerable to seismic hazard and constitute a significant percentage of earthquake losses, including both casualties and economic losses. The study presented an engineering application on seismic safety assessment of unreinforced masonry (URM) buildings in Istanbul, Turkey, a metropolitan city under very high seismic risk. Nearly 20,000 masonry buildings were examined through a two-stage assessment procedure in order to identify the addresses of those buildings which are under high seismic risk. Furthermore, the obtained database can be employed in the preparation of an earthquake mitigation strategy for the expected major earthquake in Istanbul. In the first-stage evaluation, buildings are examined visually from the street by considering their basic structural parameters and they are ranked within a priority list in terms of the calculated seismic risk. Next, the buildings identified with higher risk are evaluated in the second stage by using a more detailed procedure. The developed procedure is both an optimal and a practical tool in the seismic risk assessment of large masonry building stocks in a short period of time with limited resources (Erberik, 2010).

A performed study proposes a hybrid modeling approach for the seismic performance assessment of unreinforced masonry buildings. The method combines finite-element and equivalent-frame approaches such that more powerful features of each approach are utilized. The finite-element approach is used to model the masonry components of different geometrical and material characteristics with a high level of accuracy. Then this numerically simulated database is used in the analytical modeling of masonry buildings with equivalent beams and columns instead of spandrels and piers. Thus it becomes possible to model a masonry building as a frame structure that can simply be analyzed in order to capture the global behavior. The method has been verified by comparing the analytical results with the previous experimental findings. The last part of the study is devoted to the implementation of the method to an existing masonry building that was damaged during a severe earthquake (Aldemir, Erberik, Demirel, & Sucuoğlu, 2013). While dealing with a large building stocks, one needs rapid visual screening procedures to identify buildings susceptible to earthquake damage. Relevant structural characteristic information is collected and used to determine a structural score, which should indicate if a building requires further investigation. The study presented a procedure for rapid visual screenings for building stocks constructed in developing countries. Score sheets are prepared for three seismicity viz. low, moderate and high. Structural scores are related with damage grades I to V. The structural score <0.7 indicates high vulnerability requiring detail evaluation and retrofitting of the building (Nanda, and Majhi, 2010).

A paper addresses the large-scale classification of the seismic vulnerability of nonstructural components in school buildings. A rapid visual screening methodology is proposed that highlights the factors that likely have a major effect on the seismic behavior of nonstructural building components. This methodology is based primarily on questionnaire forms that are used to construct a nonstructural index and priority ranking that identifies the most vulnerable category of nonstructural components. Because numerical answers in the questionnaires can produce unreliable results, a calibration of the categories by weight is proposed via fragility functions to obtain a vulnerability index. Finally, the developed methodology is applied to a case study of school buildings in Italy (Angelis, & Pecce, 2015). An indexing method for rapid evaluation of the seismic vulnerability of infilled RC frame buildings in Jordan is proposed. The method aims at identifying low and medium rise residential buildings as safe or in need of further detailed evaluation. Following a rapid visual screening, the building is assigned a Basic Capacity Index (BCI); five performance modifiers are identified and multiplied by the BCI to arrive at the Capacity Index (CI) of the building. A Capacity Index lower than a limit CI value indicates that the screened building could experience moderate earthquake damage whereas a higher value implies that minor damage, if any, would take place. To establish the basic evaluation parameters; forty RC frame buildings were selected, designed and analyzed using static nonlinear analysis and incorporating the effect of infill walls. Effects of seismicity, local site conditions, horizontal irregularities (setbacks and re-entrant corners), vertical irregularities (soft story at ground floor level) and overhangs on the seismic performance of local buildings were examined. Assessment forms were designed and used to evaluate and rank 112 sample buildings. About 40% of the surveyed buildings were found to be in need of detailed evaluation to better define their seismic vulnerabilities (Al-Nimry, Resheidat, & Qeran, 2015).

Although seismic design codes are often subjected to improvements after each earthquake disaster, old constructions are left unprotected by new technology. The purpose of this paper is to promote public welfare and safety by reducing the risk of death or injury that may result from the effects of earthquakes on existing reinforced concrete (RC) building stock in Egypt. It aims to evaluate seismic vulnerability of the most commonly used type of multi-story RC buildings. Special attention is placed upon examining RC buildings with vertical irregularity. The seismic vulnerability assessment for existing RC buildings is assessed through examining two types of damage indicators: damage index and inter-story drift limit state. A sample building set is selected to reflect existing construction practice including regular buildings and those with vertical irregularities. The effects of vertical irregularity at different floor levels are examined by developing fragility curves of medium-rise gravity load designed R/C buildings. Fragility curves of the investigated building set are determined by nonlinear time history analysis to evaluate the damage state. These curves are used to represent the probabilities that the structural damages, under various levels of seismic excitation, exceed specified damage states by means of earthquake intensity damage relations. The analytical damage evaluation in this study shows that the seismic effects of earthquakes experienced in Egypt may be significant. Moreover, it shows that some of the earthquakes may impose excessive displacement demands on the investigated buildings. The results also show that the irregular buildings are more vulnerable than the regular ones (El-Kholy, El-Assaly, & Maher, 2012).

Despite the fact that it does not lie in a highly active seismic zone, Egypt suffers, from time to time, from devastating earthquakes. The building stock in Egypt is highly vulnerable to damage from earthquakes due to the rapid and uncontrollable increase of population, coupled with low quality of construction work and lack of laws that enforce seismic design regulation. The need to assess the vulnerability of the building stock to damage due to seismic loads will always be a demand. During the past two decades, the building environment in Egypt had extensively utilized medium rise RC buildings having 12 storeys, i.e., the maximum height allowed by the local authorities in most districts. These buildings are built with different configurations and structural systems having varying stiffness parameters that may have great influence on their seismic behavior. The seismic behavior of this built environment need to be thoroughly assessed. The main objective of this study was to assess the effects of varying stiffness coefficients, of columns and steel ratios of connecting beams, of this built environment, on its seismic behavior. The study aimed to improve the assessment of seismic hazard through investigating the vulnerability of this category of R.C. buildings; the seismic vulnerability will be quantified by reviewing damage indices, drift ratios and capacity curves of these buildings. The study combines the results to elaborate risk scenarios as the first fundamental step in the mitigation process. The study was carried out on a 2-dimensional model of a 12-storey building. Nonlinear dynamic analysis was performed using the computer program IDARC-6.1 (ElAssaly, 2013). A critical review and comparison of existing seismic vulnerability assessment techniques for buildings are carried out to evaluate their suitability for use in seismic risk assessment. The methods considered are “Hybrid” vulnerability assessment method, FEMA 154 (Rapid Visual Screening), Euro Code 8, New Zealand Guidelines, Modified Turkish method and NRC Guidelines. A scoring system is proposed to select the suitable vulnerability assessment technique to be utilized for three different case studies conducted in different seismicity and geological zones, that is, Dhaka, and Rangamati cities, in Bangladesh, and Kelowna, in Canada. The ranking considers general description of vulnerability, building response factors, variance in output, applicability and ease of use, which are identified as the key characteristics required for vulnerability scales used in seismic risk evaluation. A sensitivity analysis has been carried out for the different methods with regard to different weighting criteria. Furthermore, a multi-criteria decision-making tool AHP has also been utilized to find out the suitable alternatives for seismic vulnerability assessment of buildings. It was observed that the Hybrid method adequately satisfies all the criteria necessary for their use in seismic risk assessment. Vulnerability maps of different study areas using Hybrid method have been integrated into a GIS framework to visualize the building vulnerabilities in a spatial manner, which will facilitate the authority to manage effective seismic hazard risk reduction measures, including upgrading, repairing and retrofitting of structures (Alam, Alam, & Tesfamariam, 2012).

The earthquake of the 9th of July 1998 that hit in the central group of the Azores archipelago greatly affected the islands of Faial, Pico and São Jorge, reaching a magnitude of Mw 6.2 with the epicenter located about 15 km. northeast of the Faial Island. This earthquake allowed the collection of an unprecedented quantity of data concerning the characterization of the building stock and the damage suffered by construction. This is the main purpose of this research, consisting essentially of three main aspects: (i) A detailed characterization of the building stock, assigning a five category classification, from old traditional rubble stone masonry to reinforced concrete moment framed buildings; (ii) A detailed damage grade classification based on the different damage mechanisms observed; and, (iii) A seismic vulnerability assessment of the building stock. The results of the vulnerability assessment together with the building stock database and damage classification were integrated into a GIS tool, allowing the spatial visualization of damage scenarios, which is potentially useful for the planning of emergency response strategies and retrofitting priorities to mitigate and manage seismic risk (Neves, 2012).

Description of the problem

A considerable part of the existing structural stock in Turkey, as is in the countries where earthquake faults are effective, has the risk to be exposed to earthquake effects. It is seen that quite a few of the existing structures have been built under a building license and within the scope of a project despite the said truth, and also a considerable number of the existing structures leave a question mark over minds with regard to project designing, getting engineering services, and producing in compliance with the specifications (TEC, 2007; TS 500, 2000; TS 498, 1997). In this respect, it is known that quite a few of the existing buildings across Turkey have the sufficient safety and that the structures which survived many earthquake experiences in 1990s in Turkey even do not have the sufficient safety as to meet the criteria in the Specifications due to various reasons. In the evaluation of the buildings, the preparation of the structural model and analyses take a lot of time and effort (Cosgun, & Sayin, 2014a; Cosgun, & Sayin, 2014b, Gunes, Sayin, & Cosgun, 2017; Sayin, Gunes, & Cosgun, 2017). Therefore, accurate and practical solutions are needed for the buildings’ assessment.

The evaluation conditions of existing buildings

Most of the buildings are retrofitted or not after an earthquake and some of them are repaired for cosmetic purposes only. Additionally, these types of retrofits generally hide the original structural damage and therefore visual screening may be misleading. Making decisions by considering only the present view of a building is an inadequate and erroneous method. Accordingly, the reasons of previous restorations or repairs must be investigated. On the other side, some variations and modifications on the geometry of the buildings and on the structural components of the buildings are introduced during the application of repairs. The behavior, resistance and safety of two similar buildings having exactly same outside view may differ significantly depending on the inner details and alterations. Some of the alterations are relatively innocent modifications and may not change the seismic behavior of a building significantly. Changing the location or addition or alteration on non-load bearing structural components such as infill walls are some examples of this type of alterations (actually sometimes infill walls may affect the safety of a building). Some of them, which are made to save additional space such as building an additional story or demolition of a load-bearing structural member, such as a column or beam, opening holes on the structural components for additional establishments cannot be acceptable with regards of structural safety. These types of the unacceptable modifications cannot be determined easily unless the structural system of the building is investigated. Additionally, modifications are not the only necessity to affect the structural behavior of the building. For example, even though corrosion may also affect significantly, existence of the corrosion does not mean that the structure is absolutely unsafe especially for a structure having structural components with unnecessarily large sectional dimensions. Generally, a simple precaution preventing the increase of corrosion, clearing and removing the corrosion may be a sufficient procedure for these types of buildings. As an another alternative approach, which is using as built drawings of a building, is not solely reliable. Because original structure of a building may differ by unacceptable interferences or by change on the material properties within a time period. Main reasons of the possible mistakes in design can be sorted as educational inadequacy, insufficient number of experts, insufficient controlling mechanism, unplanned civilization, economical reasons, political reasons and application of unscientific and/or unproved details.

A criterion of safety requirement depends on the purpose of occupancy, type of the building and change in occupancy type that may have occurred. For example, some buildings such as hospitals dispensaries, health wards, firefighting buildings, transportation stations and terminals, power generation and distribution facilities, governorate, county and municipality administration buildings, first aid and emergency planning stations are very important buildings and can be classified as safe enough only if they have a required resisting capacity so that any important damage do not occur after an earthquake. Such buildings are absolutely necessary after an earthquake and are classified as longer period structures. Such buildings have an importance factor equal to 1.5 according to TEC2007. Schools, other educational building facilities, dormitories and hostels, military barracks, prisons, museums etc. have importance factor of 1.4, sport facilities, cinema, theatre and concert halls, etc. have as the value of 1.2 and some buildings such as residential and office buildings, hotels, building – like industrial structures, etc. with a safety which is enough to prevent loss of life under a most probable large event within a specified lifetime can be classified as a safe structure. However, such buildings may become out of service after earthquake. In this case, a structure should be pulled down easily and economically. A building may be classified as safe or unsafe depending on the using area in accordance with the considerations discussed above. For example, a school building without required safety can possibly be classified as safe enough if the building is used as a house building and satisfies the required conditions of these types of the buildings. Oppositely a house building may not be classified as a safe building if it is used for instance as a library, although it may be safe enough as a house. Therefore, occupancy of a building is an important criterion to determinate the safety of the building.

The objective of the ATC-14 project (ATC, 1987) was to develop a comprehensive but practical methodology that could guide engineers in all seismic zones of the United States in evaluating existing buildings to determine potential earthquake hazards, identify buildings and building components that presented unacceptable risk to human lives. Federal Emergency Management Agency (FEMA) developed a handbook on rapid visual screening of seismically hazardous buildings in 1987. Supporting information is contained in the ATC-21 report (FEMA, 1988). The proposed procedure is based on a “sidewalk survey” of a building and a Data Collection Form, which is completed by an inspector by visual observations. The handbook provides the inspector with background information and data required to complete the form. After grading, potentially hazardous buildings are recommended to be inspected by a professional engineer, who is experienced in seismic design. Since rapid visual screening is designed to be performed from the street without benefit of entry to the building, in some cases, hazardous details may not be visible and seismically hazardous structures may not be identified as such. Conversely, buildings identified as potentially hazardous may prove to be adequate. The purpose of the handbook (NHRP, 1992) is to provide engineers involved in the seismic evaluation of existing buildings with guidance concerning the potential earthquake – related risk to human life posed by a building or building component. The criteria of the 1988 NEHRP Recommended Provisions, which are written for the design of new buildings, are modified for the purpose of evaluating existing buildings. New edition of the handbook of FEMA (FEMA, 2002) was developed in 2002. The technical content of the new edition is based more on experiential data and less on expert judgment than was the case in the earlier edition. Most significant difference between the two editions, however, is the need for a higher level of engineering understanding and expertise on the part of the users of the second edition. This shift was needed primarily because the users of the first edition experienced difficulty in identifying the lateral-force-resisting system of a building without entry-a critical decision of the rapid visual screening process. The responses indicated that the mean time required to conduct a building survey was two hours per building. Workshop participants indicated that the methodology was easy to explain and grasp, but that implementation was sometimes difficult, principally because of the difficulty in determining the structural system without access to plans, to the building interior, and for remodeled buildings and those with numerous additions, and the soil conditions for the site. Users also discussed the difficulty in information sharing and identified the varied uses of the methodology. Therefore, basic structural hazard scores and performance modification factors are updated.

Methodology

The proposed method depends on a questionnaire of eleven-stages, which is completed inside the building. The structure identification includes questions, which are thought to be the most important parameters to estimate the safety conditions of a building. Some of the answers of such questions are included in order to determinate the parameters for the dynamic analysis of the building in accordance with TEC-2007. Remaining questions are included to determine geometric and material properties of the building. Following can be obtained by using the answers of the field data.

- Self-weight (dead and live loads) and lateral loads (wind and earthquake),
- Dynamic analysis of the building at both directions,
- Bending shearing and overturning behavior of the building,
- Soil stresses,
- Safety of the building with respect to vertical and lateral loads.
- Additionally, automatic data generation for a finite element model (Oztorun, Citipitioglu, & Akkas, 1995).

The loads acting on the building with respect to load-carrying capacity of the building can be obtained very easily and rapidly. Reliable analysis results can be obtained when compared with more complicated analysis techniques. Then the existing buildings can be classified relatively considering the existing safety conditions. A computer program named as “DURTES” which is based on this methodology is developed for the purpose of rapid estimation of the buildings for potential seismic hazard.

Computer Program

The software using the algorithm of the method, which was developed within the scope of the offered method, was first developed by using BASIC programming language, and then Visual Basic and PHP programming languages. JAVA programming language is being used for the method, which is still being developed under the current conditions (JAVA, 2016; PHP, 2016; Turbo Basic, 2003; Visual Basic, 2013).

In the most general sense, the offered method consists of four main sections, which are data stages, data entry module, analysis module and reporting module. The first three sections are supposed to be completed in order to determine the safety level of a structure quickly, and the reporting module is optional. Each module also involves sub-sections themselves. For example, the data entry module involves the floor plan entry section and it is optional to use it. If there are sufficient structural details, which was analyzed before and for which the data entry process was applied before, it is not obligatory to use the said sub-section even though it is suggested. In cases where it is not possible to access any data related to the section and geometric system of the structural members within the scope of the structural study for any reason (the cases where it is not allowed to examine in detail due to the complexity of the structural geometry or safety, or where it is required to accomplish a result within a very short time), even if the related structure is not subject to the examination, it is possible to determine the safety of the structure that is examined with the closest accuracy. The said process is carried out by using the iterative interpolation value featured in the method. If the structural data on the database of the software featuring the algorithm of the method are extensive, it can provide a better assumption related to the safety of structures, the floor plans of which are unrecorded.

The structural evaluation process, which contains the data used within the method, begins after filling the survey forms in the structure and continues with the entry of said data into developed software. The safety level of the structure that is subject to the analysis is determined within 1 to 2 seconds following the entry of the structural data into the software. Similarly, it is also possible to receive the structural safety report (assessment report) within 1 second by using the automatic reporting module of the software that has been developed with the purpose of quick evaluation.

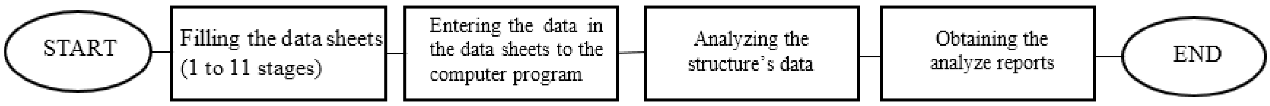
The main options of the developed computer program “DURTES” is stated in below:

- Easy and rapid interactive data input.
- Producing a database for each building.
- Producing an output data including building identification numbers and building coordinates.
- Control of error and missing data entrance.
- Performing simple dynamic analyses of the buildings individually in accordance with TEC-2007.
- Performing dynamic analyses of all buildings under consideration automatically.
- Producing individual output reports for word processing program for a building together with the picture of the building optionally. Output reports consist of the echo print of the input data and analysis results in detailed form for an individual building. Some suggestions and recommendations are also included in these reports automatically.
- Producing output reports for all buildings of the project automatically.
- Classifying the buildings in accordance with the pre-described criteria and tabulating the buildings. A summary table including the number of the buildings with most common properties is also presented by the computer program (for example buildings with two basements or buildings having short column problem etc.).
- Tabulating the buildings in accordance with manually defined criterion. A special grouping such as the buildings “(with flat slab) and (with single foundation or mat foundation) and (having more than five stories) and (only one basement) and (having A1 type of imperfection) etc.” is also possible.
- Automatic producing input data for cad and MapInfo computer softwares. The coordinates of the building included in the group under consideration can be transferred to excel, cad and MapInfo computer programs automatically and the results can be presented in those media. The required data is available within the database of each building and the developed computer program utilizes this data.

The algorithm and solution procedures

Schematic indication, which flow process of developed technique is represented, is displayed in Figure 1 in the most general form. There are subparts in this flow process and the flow diagram where these parts are located could be seen in Figures 2 and 3.

Figure 1. Flowchart of proposed method. Source: Gürsoy, Yildizlar, Öztorun, Çelik (2003b).



Structure identification

The data entry process required to determine the safety level of a structure on the software prepared for the developed method may be carried out under 11 main topics. The main topics are respectively coding date, address of the building, general data, specification coefficients, structural properties, material properties for concrete buildings, damage condition, and design problems, reason of damage and location of the structural components. The topic "first data entry" includes the information about the examination date and whether there are any existing projects related to the structure that is subject to the examination. Because if access to the existing projects of the structure is granted, it is required to check their compliance with the projects featuring production. If the projects are not available, the issues are evaluated at the 11th data entry section. Finally, the floor area of the structure is questioned in the first stage. Usually basements or ground floors are taken into consideration as the said floor area and the other floor areas are created by using the acquired data on the floor area.

The second and third stages of the data entry process include only the information based in reporting module, except for the structural evaluation criteria, and are not included in the evaluation process. Names, last names and group information of the professional team members examining the structure on-site in the first of the aforementioned two sections. The said group information specifically refers to the team number of technical experts who work in groups during the extensive field scanning works. As for the other data, they include the address information of the examined structure and the information about the person who is responsible for the said structure and gathering information about it. In case that project or reports of any structure cannot be supplied or do not exist, it is foreseen that applying to persons who have information about the structure is going to be beneficial.

In General Data part, which is the fourth part, age of the structure, whether the structure was damaged before and after the last great earthquake or not, including structural elements of this case in case of maintenance or existence of visual and cosmetic maintenance are questioned. In this questioning, every different information taken from the structure makes positive and negative contribution to point of score. On the other hand, after recording the weight of structure, the number of basements in the structure, the number of normal floors, the height of the relevant floors, whether there is garret or not, rate of field of garret to field of floor in case of existing garret, and information of average floor weight existing in square meter are demanded for calculating earthquake forces; in addition to this, maximum clearance between vertical elements in terms of point of score, maximum floor level between structural structures, information about whether difference and dilation are sufficient or not are questioned.

Figure 2. Macro flow-chart of the developed computer program "DURTES": Part 1. Source: Gürsoy, Yildizlar, Öztorun, Çelik (2003b).

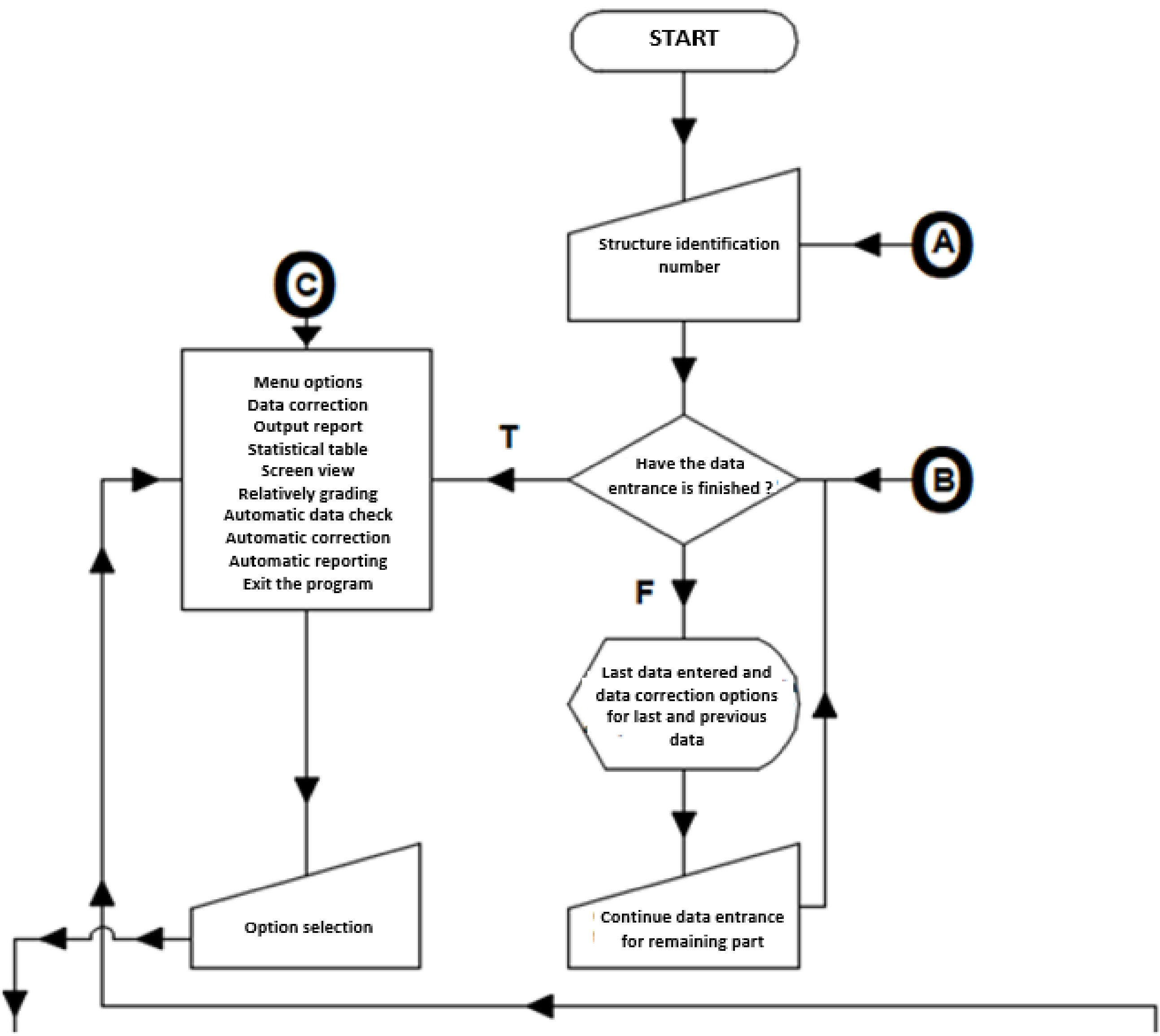
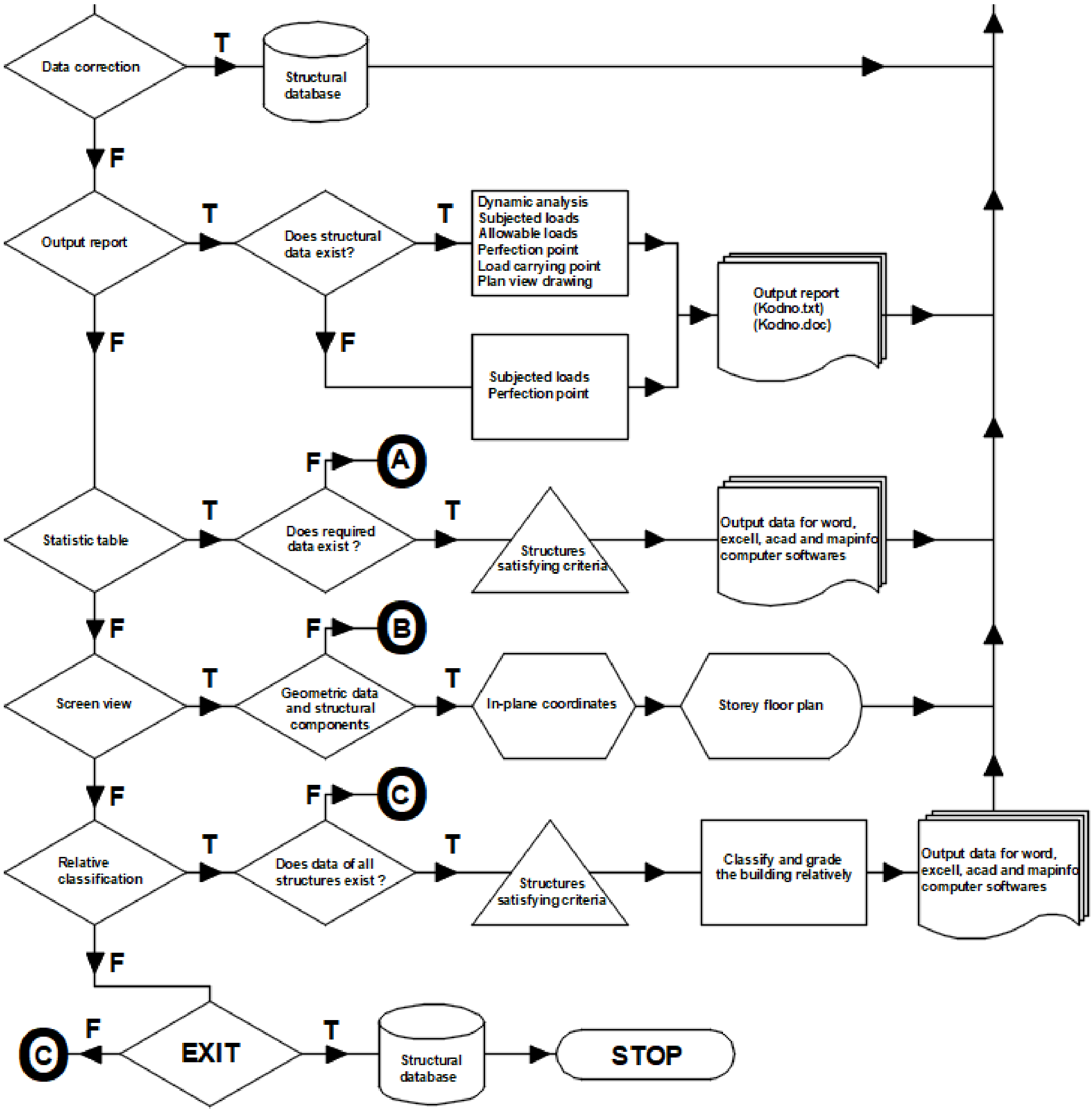


Figure 3. Macro flow-chart of the developed computer program "DURTES":Part 2 (continue). Source: Gürsoy, Yildizlar, Öztorun, Çelik (2003b).



In the fifth part which is Specification Coefficients, there are agreement parameters related to the structure such as structural importance factor, purpose of occupancy and structural behavior coefficient, besides soil properties such like seismic zone, local site class. By using data gained by relevant parameters and other parts, the value of base shear force and its distribution on floor basis are calculated by the software.

In the sixth part, there are properties of conveyor system of the structure whose structural conveyor system is researched. It includes the information on the type of conveyor system (framed, frame and shear walls, shear wall, masonry, steel, Timber, or composite structure), whether there is difference in type of floor system and throughout the structure (beam, bare joist, in filled joist, flat, cassette or other) or not, type of foundation system (single, continuous, mat, pile or other) and if available, outer walls of the basement concrete wall, stone, concrete brick, block brick, holed brick or other). Structural mark value changes in accordance with the information obtained through these questions.

In case that the structure examined in the seventh part is concrete reinforced, it leads to determination of properties of the existing material. Data belonging to longitudinal- and transverse-rebar type is gained by using nondestructive techniques by the team that examines data of compressive strength of the concrete in average, compressive strength of concrete of most heavily damaged column and concrete workmanship quality.

The eighth data entry part has been determined as the part where existent damage status of the structure is detected. In the software, structural damage status is demanded on scale of group of element type, not in element basis. These structural element groups were classified into columns, shear walls, beams, plates, stairs and basic elements. The requested amount of damage is taken from only floors which have the heaviest damage. If available, within the most damaged floor, the method requires rate of crossing field being heavily damaged, moderately damaged and lightly damaged on the scale of column and shear wall elements, and also rate of damaged crossing on scale of beam, plate and stair elements, without paying regard the category, to rate of total crossing. Since data cannot be obtained in many cases related to footing block, whether there is only deformation as a determination of damage in the basis or not and damage rate, if it could be determined, are involved within the algorithm.

The ninth data field was characterized as the part which design problems were detected throughout the structure. Among these investigated defects, short column problem, rigid beam – flexible column, intermediate story floor and cantilever story floor existence are questioned. On the other hand, it includes data related to geometrical irregularities pursuant to TEC-2007 specification. There is a checklist that material detailing and workmanship imperfections factors are questioned in these questioning stage, throughout the structure.

In the tenth data field, there is also a different checklist that possible problems in case of existing damaged structure and solution suggestions for such problems are included.

In the eleventh data field, which is the last part of data entry process, there is schematic field designed to be able to draw floor plan belonging to structure that structural safety determination was projected. This field is proper for only one floor plan, and there is only one floor plan on data requested by the technique. The said information consists of data belonging to section and location of vertical conveyor structural elements placed basement or ground floor.

The structural safety factor of the structure can be gained and then safety level can be determined when eleven phased data is provided. As stated previously, in case that relevant floor plan cannot be obtained due to any reason, estimated structural safety factor data is obtained, and safety level of the structure is estimated by the method close to the exact value. In Turkey, there are some studies related to determination technique of mentioned case and implementation of this method (Gürsoy et al., 2003a; Damci et al., 2003; Yildizlar et al., 2003; Gürsoy et al., 2003b). However, although the method continued to be developed by authors, the studies remained at the level of limited number and of national announcement. In this study, this new method for determination of the situation was tried to be expressed. Also, there are still studies related to potential implementation of the method, which are published from time to time.

Conclusions

Within the study, a structural safety determination and estimation method which is based on mathematical principles developed with minimum parameters are presented. It is possible to accomplish correct and tangible results concerning the examined structure or structures by the scores and determinations obtained from the method. It is possible to determine only one structure safety via this method as well as it offers using opportunity for scanning studies of structures in regional scale. It is right to point out that the offered method is rapid due to said property, and thus it is different than approximate or exact solutions based on this property. Another property separating this method from other studies is the approaches related to "Structural Safety Factor" and" Estimated Structural Safety Factor". The structural safety factor approach is characterized as approach giving similarity results like results gained in consequence of calculations made in detailed via the most developed finite element software (SAP2000, 2016; ETABS, 2015) that continue for a long time. In the "Structural Safety Factor" approach, total base shear force entering to building and earthquake load, could be encountered with existing vertical conveyor element crossing of the structure are compared by using information, whose data entry was made within the method, with the help of algorithm. In consequence of comparison, structural safety factor is obtained, and safety level of the structure is determined according to relevant agreement and standards clearly. When there are numerous buildings to evaluate, the "Estimated structural safety factor" approach which gives correct results is recommended as well as in cases with limited time and financial opportunities. In line with this approach, building surveys are carried out, which make it possible to create enough databases to reflect the properties of a structural group in a classification of structure types. In this way, the best results are accomplished and this makes it possible to make decisions about the safety of structures in cases where surveying information related to the structures cannot be identified. By using the developed method with mentioned properties, it is completed in a short time to examine all structures in urbanized fields in province and distinct scale having many structure population and to determine structural safety levels, and thus safety levels of existing structures in regions under the examination against the earthquake risk might be determined.

Alam, N., Alam, M.S., & Tesfamariam, S. (2012). Buildings' seismic vulnerability assessment methods: a comparative study. *Natural Hazards, 62*(2), 405-424, http://doi.org/10.1007/s11069-011-0082-4

Aldemir, A., Erberik M.A., Demirel, I.O., & Sucuoğlu H. (2013). Seismic performance assessment of unreinforced masonry buildings with a hybrid modeling approach. *Earthquake Spectra 29*(1), 33-57, https://doi.org/10.1193/1.4000102

Al-Nimry, H., Resheidat, M., Qeran, S. (2015). Rapid assessment for seismic vulnerability of low and medium rise infilled RC frame buildings. *Earthquake Engineering and Engineering Vibration, 14*(2), 275-293, http://doi.org/ 10.1007/s11803-015-0023-4

Angelis, A., & Pecce M. (2015). Seismic nonstructural vulnerability assessment in school buildings. *Natural Hazards, 79*(2), 1333-58, http://doi.org/10.1007/s11069-015-1907-3

ATC-14 (1987) *Evaluation the Seismic Resistance of existing Buildings.* Applied Technology Council, 3 Twin Dolphin Drive, Suite 275, Redwood City, California.

Coşgun T., & Sayin B. (2014a). Geometric and material nonlinear analysis of three-dimensional steel frames. *International Journal of Steel Structures, 14*(1), 59-71. http://doi.org/10.1007/s13296-014-1007-3

Coşgun T., & Sayin B. (2014b). A method for the non-linear and failure load analysis of reinforced concrete frames. *Computers and Concrete, 14*(1), 41-57, http://doi.org/10.12989/cac.2014.14.1.041

Damci, E., Yildizlar, B., Gürsoy, G., Öztorun N.K., & Çelik T. (2003) *Algorithm for determination of structure situation in only Bakirköy and throughout Turkey*. Fifth National Earthquake Engineering Conference, Istanbul, Turkey.

ElAssaly, M. (2013). Towards seismic vulnerability assessment of the building stock in Egypt. *The Arabian Journal for Science and Engineering, 38*(11), 2953-2969, http://doi.org/ 10.1007/s13369-012-0467-z

El-Kholy, S.A., Assaly, M.S., & Maher, M. (2012). Seismic vulnerability assessment of existing multi-story reinforced concrete buildings in Egypt. *The Arabian Journal for Science and Engineering, 37*(2), 341-355, http://doi.org/ 10.1007/s13369-012-0170-0

Erberik, M.A. (2010). Seismic risk assessment of masonry buildings in Istanbul for effective risk mitigation. *Earthquake Spectra, 26*(4), 967-982, https://doi.org/10.1193/1.3464344

ETABS (2015). *Integrated building design software.* Computer and Structures, Inc. CA 94704, Nonlinear Version 15, University Avenue Berkeley.

FEMA-Federal Emergency Management Agency. (1988). *Rapid Visual Screening of Buildings for Potential Seismic Hazards.* Handbook, ATC-21, Applied Technology Council, 3 Twin Dolphin Drive, Redwood City, California 94065 (April, 1988).

FEMA-Federal Emergency Management Agency. (2002). *Rapid Visual Screening of Buildings for Potential Seismic Hazards.* Supporting Documentation, Earthquake hazards Reduction Series 41, Applied Technology Council, 555 Twin Dolphin Drive, Suite 550, Redwood City, California 94065 (Fema 155/March, 2002).

Gunes B., Sayin B., Cosgun T. (2017) "Nonlinear static analysis of an existing RC building using fiber section modelling" ICENS 2017: III. International Conference on Engineering and Natural Science, Budapest, Hungary, May 3-7, 2017.

Gürsoy, G., Yildizlar, B., Öztorun, N.K., & Çelik, T. (2003a). *Recommended technique for determination of situation of existing structure stock in terms of earthquake risk and Bakirköy district data.* MBGAK'2003: Engineering Sciences Young Researchers 1th Congress, Istanbul.

Gürsoy, M.G., Yildizlar, B., Öztorun, N.K., & Çelik, T. (2003b). *New technique for earthquake scanning risk in urbanized fields.* Küçükçekmece and Near Environment Technical Congress, Earthquake and Planning, 639-648.

Jain, S.K., Mitra, K., Kumar, M., & Shah, M. (2010). A proposed rapid visual screening procedure for seismic evaluation of RC-frame buildings in India. *Earthquake Spectra, 26*(3), 709-729, https://doi.org/10.1193/1.3456711

JAVA-Sun Microsystems (2016). Java Programming Language World Wide Web Site. http://java.sun.com

Nanda R.P., Majhi, D.R. (2014). Rapid seismic vulnerability assessment of building stocks for developing countries. *KSCE Journal of Civil Engineering, 18*(7), 2218-2226, http://doi.org/ 10.1007/s12205-014-0050-0

Neves F., Costa, A., Vicente, R., Oliveira, C.S., & Varum, H. (2012). Seismic vulnerability assessment and characterization of the buildings on Faial Island, Azores. *Bulletin of Earthquake Engineering, 10*(1), 27-44, http://doi.org/ 10.1007/s10518-011-9276-0

NHRP-National Earthquake Hazards Reduction Program. (1992). *Handbook for the Seismic Evaluation of existing buildings.* Developed by the Building Seismic Council for the Federal Emergency Management Agency based on a Preliminary Version Prepared by the Applied Technology Council.

Oztorun N.K., Citipitioglu, E., & Akkas, N. (1995). *Mesh generation and data structures for the finite element analysis of shear wall buildings.* Developments in Computational Techniques for Structural Engineering, Proceedings of the Sixth International Conference on Civil and Structural Engineering Computing (ed. B.H.V. Topping), 367-382 (Cambridge, England).

PHP- Hypertext Preprocessor (2016). http://www.php.net (Accessed date: September 2016)

SAP2000. (2016). V17, Integrated Software for Structural Analysis & Design, Computers and Structures Inc.

Sayin B., Gunes B., Cosgun T. (2017) "Seismic assessment of a masonry building according to TSC2007: A case study" ICENS 2017: III. International Conference on Engineering and Natural Science, Budapest, Hungary, May 3-7, 2017.

Sucuoğlu, H., Yazgan, U., & Yakut A. (2007). A screening procedure for seismic risk assessment in urban building stocks. *Earthquake Spectra, 23*(2), 441-458, https://doi.org/10.1193/1.2720931

TEC-2007 (2007). *Turkish Earthquake Code, Specification for Buildings to be Built in Earthquake Regions*. Ministry of Public Works and Settlement, Government of the Republic of Turkey.

TS 500 (2000). *Turkish Standards 500, Requirements for design and construction of reinforced concrete structures.* Turkish Standards Institute, Ankara, Turkey.

TS 498 (1997). *Turkish Standards 498, The loads and loading cases due to use and occupancy in residential and public buildings*. Turkish Standards Institute, Ankara, Turkey.

Turbo Basic (2003) Robert "Bob" Zale, 1945-2002

Visual Basic (2013) Microsoft Corporation https://msdn.microsoft.com/tr-tr/en%20us/vstudio/ %20hh388573.aspx

Yildizlar, B., Gürsoy, M.G., Öztorun, N.K., & Çelik T. (2003*). Recommended technique with Bakirköy district example for determination of situation of existing structure stock in terms of earthquake risk.* Earthquake Symposium, Kocaeli, Turkey.