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A Simulation Technique for Controlled Demolition of Buildings

[1]Volkan TAVŞAN, [1]Ali GÜRBÜZ, [2]Temel TÜRKER

1Recep Tayyip Erdogan University, Department of Civil Engineering, Rize, Turkey.
2Karadeniz Technical University, Department of Civil Engineering, Trabzon, Turkey.
Corresponding Author: ali.gurbuz@erdogan.edu.tr

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Abstract

The fact that there are some structures, which is unlicensed or is vulnerable to or expire their lifetime, has led to the search for new demolition techniques in order to be carried out urban transformation studies faster and more effectively. Due to the many advantages of controlled demolition of buildings by explosives, which have been successfully applied for many years. When this method applied properly on structures, such as towers, chimneys, silos, bridges etc., it has wider application are at hant raditional demolition techniques due to lower cost and faster method. The most common problem inbuilding demolition by explosives is that the building does not collapse or collapse in the desired direction. The amount of charge, hole design, delay interval and blasting sequence must be determined correctly for the most accurate planning of controlled demolition of buildings. Simulation of the finite element model in the planning of his process is beneficial for the design of the demolition that is closest to reality. For this purpose, a simulation program has been prepared to analyze the structural behavior of the buildings which planned to be demolished by using explosives and to ensure that the demolition mechanism can be estimated as close to reality as possible. In this simulation program, demolition design of a typical reinforced concrete structure has been prepared.

1 INTRODUCTION

The buildings that have been completed in the past century need to be designed and renovated or demolished in accordance with engineering criteria for the different reasons (Gunes et al., 2019). Considering Turkey as an example, after the Van earthquake in 2011, necessary steps were taken to renew/demolish unauthorized or dangerous structures. Accordingly, 2012, on May 31, a new law (Number: 6306) called "Renewal of Areas at Risk of Disaster" was prepared and thus urban renewal projects were started throughout Turkey (Kentsel Dönüşüm, 2014). Due to the fact that a large part of the country is located within the first and second degree earthquake zone. It is predicted that approximately 6700000 houses will be demolished and rebuilt in the next 20 years, which means that an average of 334000 buildings per year must be demolished and rebuilt (Kentsel Dönüşüm, 2014).

The demolition of buildings by conventional methods is disturbing the environment because it

takes a long time; it also causes high costs and has unsafe working conditions (Özyurt et. al., 2016). The demolition of these structures by traditional methods by inexperienced and uninformed people leads to dangerous consequences. Therefore, a more useful technique was explored and as a result of the studies which started on the basis of the British Standard titled "BS 6187:2011 Code of Practice for Full and Partial Demolition", the Turkish Standard titled "TS 13633" was published in October 2014.

The construction demolition technique by explosives has advantages such as fast application, low cost in high-rise buildings, minimising work accidents, limiting and controlling the impact on the environment over a short period of time (C. Jimeno, E. Jimeno and Carceda, 1995; Koca,2006). However, the construction demolition technique by explosives has disadvantages such as the possibility of damage to nearby buildings, failure to completely demolish the structure, failure to perform the demolition in the desired direction (Tavsan et al., 2020). Demolition planning should be carefully prepared in order to avoid an undesirable situation in building demolition by explosives, blasting demolition work should be carried out by people that have experience and necessary simulations should be carried out in order to predict realistically the demolitionmechanism.

The correct preparation of demolition planning and the investigation of structural behavior is very important for the successful implementation of explosive demolition method and there are various studies in this area (Koca, 2006).

Although there are quite developed professional softwares for controlled demolition of structures by explosives, due to high price, operations are usually performed depending on experience. As a result undesirable situations have been occured.

The method proposed in this study is based on the carrier elements to be detonated on the finite element model are selected and erased. Thus evaluation is possible the deformation shape of the structure. As a result of the evaluation, if the demolition direction is in an inappropriate direction, the demolition process is returned to the beginning and the process is repeated. It is very important that these processes, which take a lot of time, can be performed more effectively and quickly. In this study, in order to prevent time loss and to determine the demolition direction of the structure realistically, in the simulation program created by enabling MATLAB and SAP2000 to work together, the carrier elements to be detonated on the finite element model are selected and erased, then the deformation shape of the structure is examined step by step. In this way, the order of the

carrier elements that must be detonated in order to collapse the structure in the intended direction can be determined and as a result the most suitable demolition design can be obtained. If the demolition direction of the simulated system in the program that is created is not as desired , the process steps can be taken back and a new design can be created. As a result of this, the design of the detonation that will allow the structure to fall in the desired direction can be presented.

2. COMPUTER MODEL OF SELECTED BUILDING

In the simulation program, the demolition of a selected typical structure was simulated. The chosen structure is a 10-storey reinforced concrete building that has an axle length of 4.5x5m. The building concrete class was assumed to be C25, the steel class is S420, all beams are 30x60 cm and all columns are 35x35 cm. The formation of plastic hinges in the structure has been neglected during the blasting period as the sudden collapse condition is desired to occur in the demolition design. Horizontal cumulative displacements are taken as a basis in the design of the demolition. The largest horizontal displacement value was determined by considering the relative storey displacement rate. In order to be analyzed controlled demolition by blasting in a computer environment, a structure model must be created by any finite element program (Yılmaz, 2006; Özyurt et. al., 2016; Özmen et. al., 2017). In this study, the structure modeled by SAP2000 program and the floor plan of the structure are given in Figure 1.

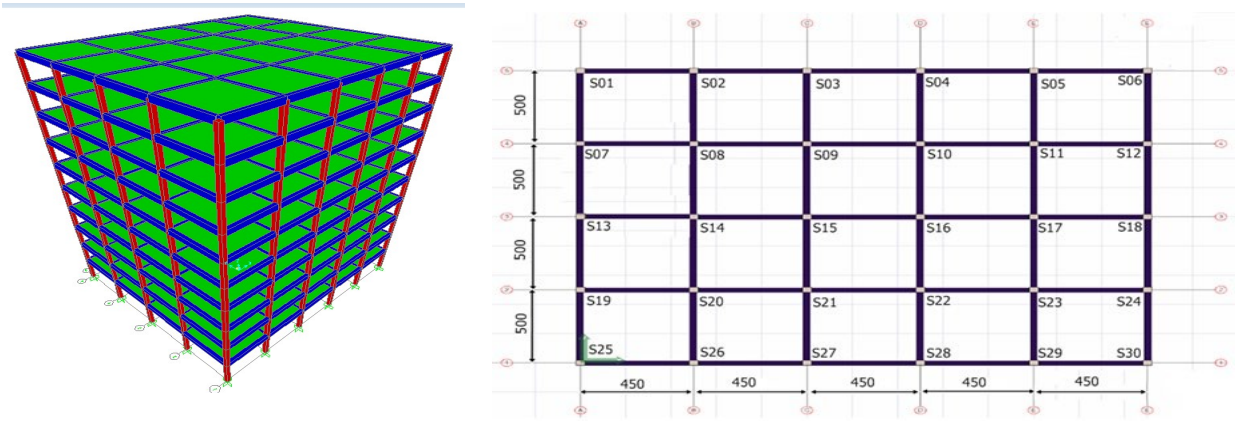


Figure 1. Floor plan and 3D model of the structure to be demolished

3. DEVELOPED SIMULATION PROGRAM

the program purposed in this article is created by enabling MATLAB and SAP2000 to work together. The steps for the demolition simulation program developed are presented in the algorithm of Figure 2.

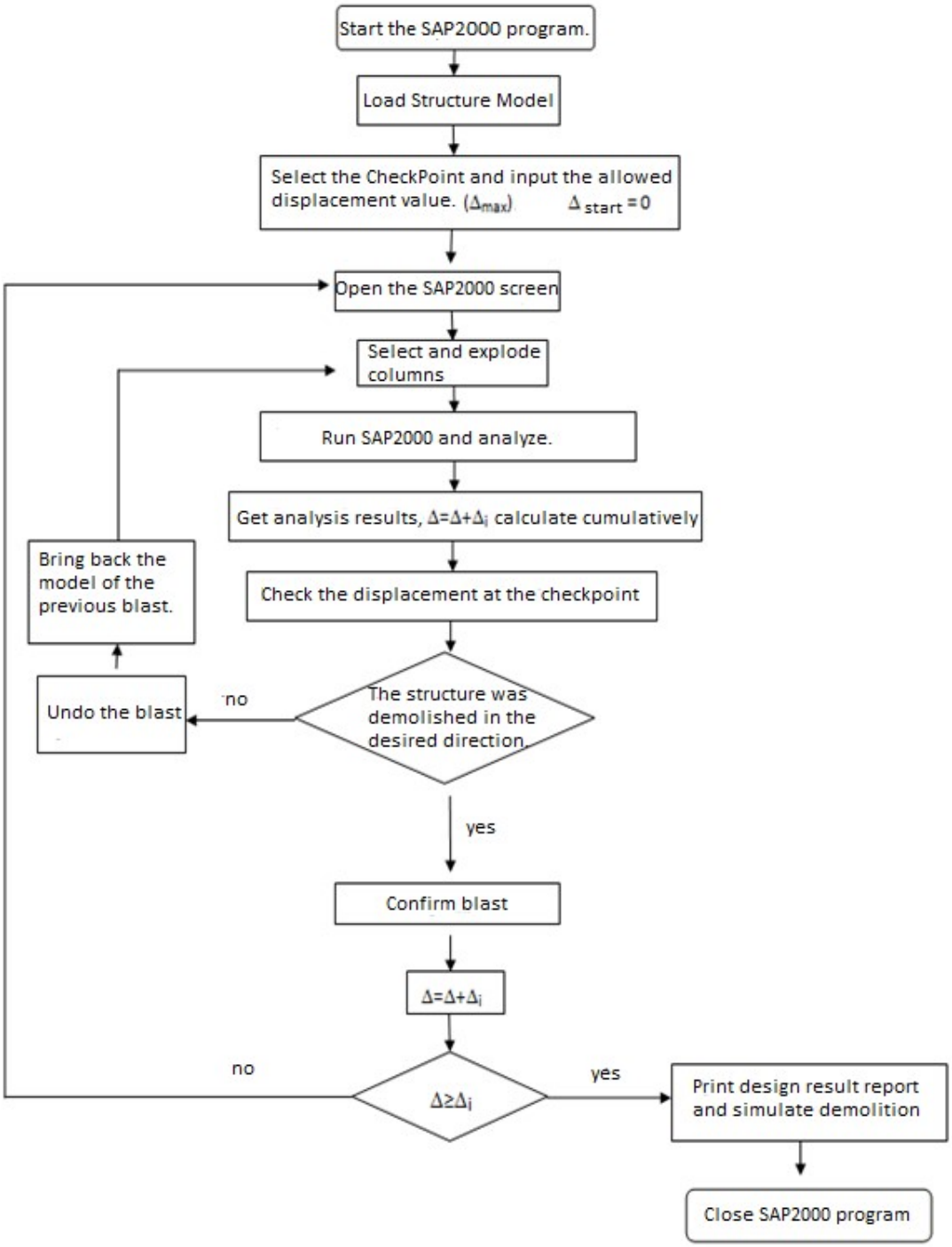


Figure 2. Algorithm of simulation program

In the first step, Sap2000 model of the structure is created ordinary. In controlled demolition of any structure, the carrier elements must be detonated in a certain order to be determined the direction of demolition.Inorder to be determined this order, the analysis must be performed step by step as elements are removed from the structure. This simulation program that works together with MATLAB program was created for the step-by-step analysis of the controlled demolition of a structure (Figure3

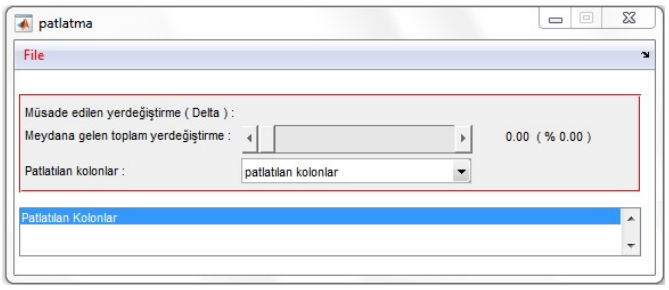


Figure 3. Interface of simulation program

Second step is transfer of 3d model of the example structure to the simulation program. For detailed analysis of the cumulative deformation of the structure model, in the simulation program, by being clicked on the 'Open_SAP2000_sdb_file' button in the 'File' tab, SAP2000 program is automatically opened in the background. In the 'Select the sdb file' section, the structure model was named "model_1" or etc. Transfer of structure model to the simulation program is shown on figure 4.

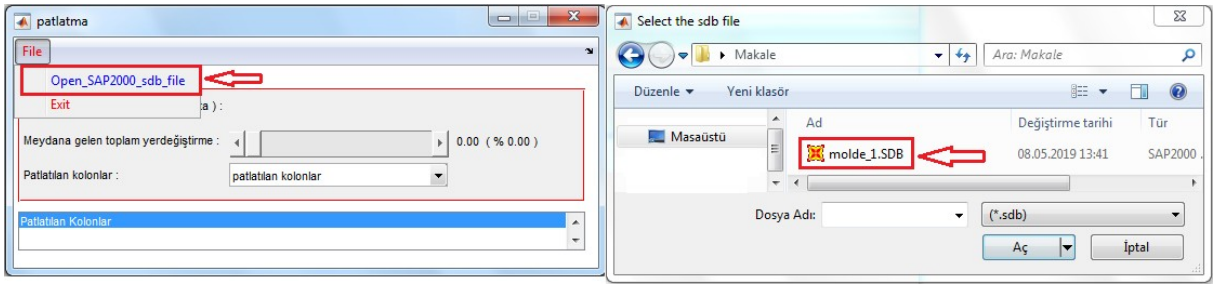


Figure 4. Transfer of structure model to the simulation program

In this transfer process, the data file of the structure is transferred to the MATLAB program, so every change made in this data file is automatically saved to the MATLAB program.

In third step; SAP2000 program calculates the value of the deformation that occurs in the demolition of the structure model, can not give information about whether the structure will collapse or not. Therefore, in order to be determined whether the structure will collapse or not, a different control point is selected for each structure on the program and the displacement value at this checkpoint is compared to the maximum displacement value assigned to the program. In this way it can be decided whether the structure has collapsed or not. For this example structure, the maximum horizontal displacement at point 303 is considered as 120cm.

In the structure, click on the 'Explode Column' button and "confirm detonation" button to be determined the order of the bearing elements to be detonated and the SAP2000 program is opened automatically.

According to the intended demolition direction, the user decides which carrier elements to delete in the structure model in the SAP2000 program.

In the next step, if the structure tends to demolish in the desired direction but the deformation value (in this example; 0.0030221 m) does not exceed the maximum deformation value (in this example 1.2 m), a second blasting design is needed.

In the second blasting design, the structure model formed by the first detonation is taken into account (Figure 14). Then, the carrier elements are selected and deleted in the program according to the order

determined for the second time (Figure 17&Figure 18).Inthe SAP2000 program, the final structure model is analyzed.

In the next step, if the structure tends to demolish in the desired direction but the deformation value (in this example; 0.003+0.0135=0.0165 m) does not exceed the maximum deformation value (in this example; 1.2 m), a third blasting design is needed. The analysis is continued until sufficient carrier elements are deleted.

If the structure does not collapse in the desired direction in the simulation, the structure model is automatically restored to its previous state by being clicked on the 'Undo explosion' button in the interface program. In this step, the model must be restored to the previous one. Because the structure tends towards the Y-axis and this situation is not desired. Then a different blasting design must be created.

For the controlled demolition of the example structure, the carrier elements were selected and deleted in the program according to the order determined for the fifth time. In fifth blasting, the structure collapsed to the desired direction and the deformation value (3.6865 m) exceeds the maximum deformation value (1.2 m). The last step of demolition design is shown on figure5. Finally, this design can be used as a "demolition design" (Figure26).

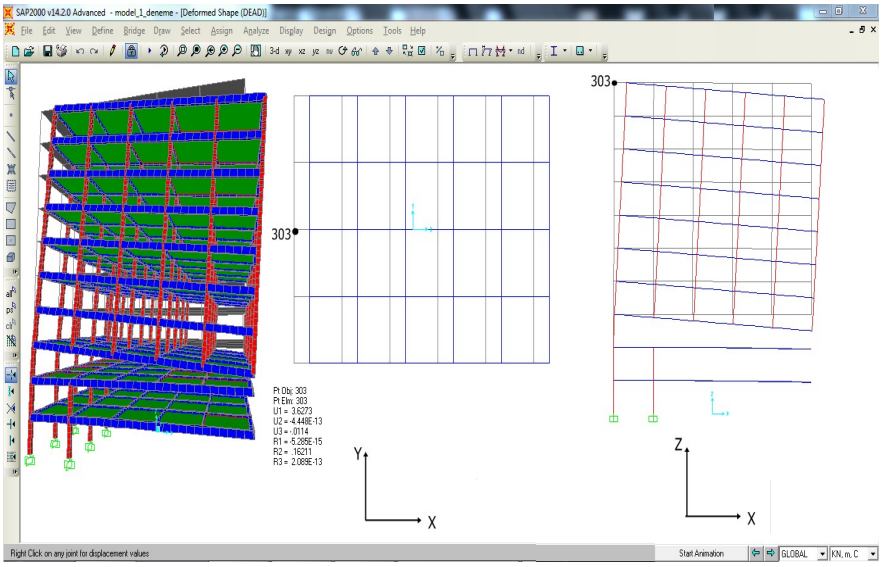
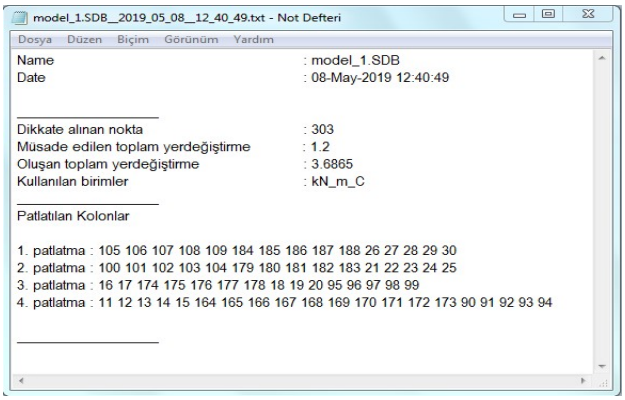


Figure 5. Analysis results of the last blasting design

After the suitable demolition design is obtained, the blasting process is stopped and the design report is prepared automatically by the program (Figure 6).


model_1.SDB__2019_05_08__12_40_49.txt - Not Defteri

Dosya Düzen Biçim Görünüm Yardım

Name : model_1.SDB
Date : 08-May-2019 12:40:49

Dikkate alınan nokta : 303
Müsade edilen toplam yerdeğiştirme : 1.2
Oluşan toplam yerdeğiştirme : 3.6865
Kullanılan birimler : kN_m_C

Patlatılan Kolonlar

1. patlatma : 105 106 107 108 109 184 185 186 187 188 26 27 28 29 30
2. patlatma : 100 101 102 103 104 179 180 181 182 183 21 22 23 24 25
3. patlatma : 16 17 174 175 176 177 178 18 19 20 95 96 97 98 99
4. patlatma : 11 12 13 14 15 164 165 166 167 168 169 170 171 172 173 90 91 92 93 94

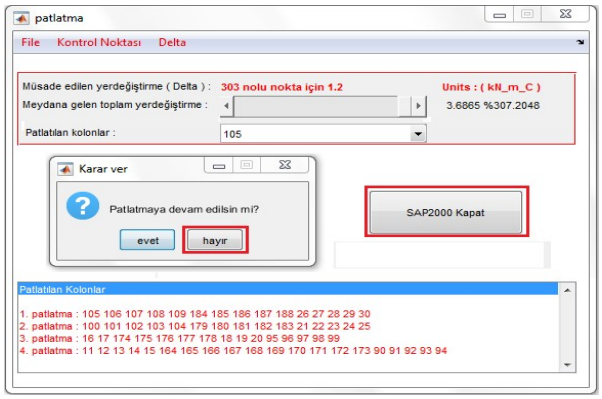


Figure 6. Finalizing the demolition design and design report

By being clicked on the “No” button in the ’decide‘ window, the data of the demolished structure is automatically saved in txt format along with the analysis date and time in the folder named ’Blasting reports'. Finally, the "Design results’ is opened and the number and order of the bearing elements to be detonated is determined as shown in Figure 6 also.

4. CONCLUSION

In this study, a simulation program that based on structural analyses that performed on finite element models was created in order to prevent to demolished in undesired directions, the most important problem faced in the demolition of structures by explosives. The applicability of this program is demonstrated by being designed demolition of a selected typical reinforced concrete structure in the desired direction. The following results were obtained from this study:

- It has been revealed that controlled demolition design of structures by explosives can be made more effectively with structural assessments that based on finite element analyses.
- It has been shown that the demolition of the selected reinforced concrete building can be carried out in the desired direction with this simulation program.
- Thanks to the report generated by the simulation program, the order of the elements to be detonated in demolition was determined.
- Because the demolition is aimed to be carried out in the most economical way, a blasting design which includes blasting a minimum number of structural elements has been revealed.

Demolition design by explosives is a applicable approach for structures such as buildings, towers, bridges. It is thought that blasting demolition can be done more effectively, if this approach and simulation program which is created by running matlab and sap2000 programs together.

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