O 104. THE EFFECT OF DIFFERENT SEISMIC ISOLATOR TYPES AND FLOOR NUMBER TO EARTHQUAKE BEHAVIOR ON MULTI-STOREY REINFORCED CONCRETE STRUCTURES

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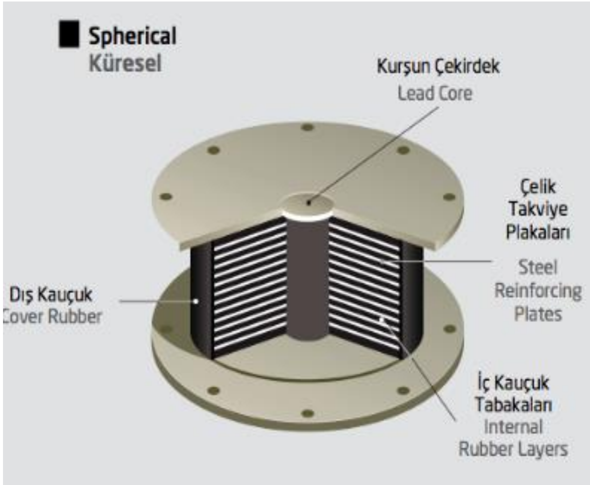
ABSTRACT: Earthquakes are uncontrollable natural disasters that cannot be predicted in time. Turkey, located in a region of high seismicity. Seismic isolation is an earthquake resistant structure design approach based on the principle of increasing the resistance of the structure against earthquakes or reducing the seismic forces transferred from the ground to the structure. In this study, an exemplary health center RC building system, carriage elements are dimensioned according to TS-500 (Turkey Concrete Structures Design and Construction Rules) and TBDY-2018 (Turkey Building Earthquake Regulation). 3 models were created for the same building according to three different types of support (with friction pendulum isolation system, lead core rubber bearing isolation system, fixed base dual system) .The most important aim of this study is to find out which of the seismic isolator type is more effective than fixed base dual systems. These models were analyzed nonlinear (FNA) in time domain in SAP2000 program. When compared with seismic isolator bearing systems and fixed base dual systems; the internal forces, the relative drift ratio(%) of the floor and the acceleration of the floor were decreased, but the natural vibration period was increased. The system with friction pendulum isolator has better earthquake behavior than the system with lead core rubber.

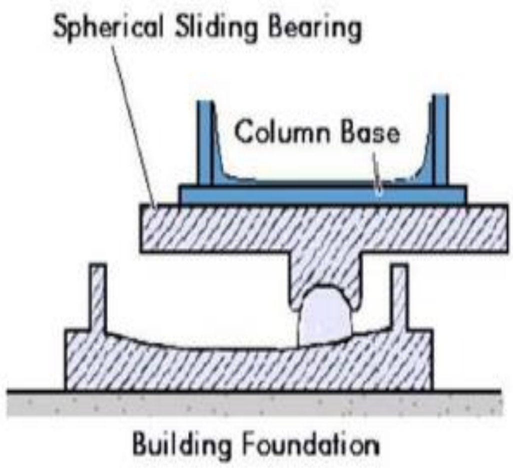
Keywords: *Core, Isolator, Seismic, Pendulum, Rubber*

1.INTRODUCTION

The main aim of the present study is to investigate the effects of one of the structural control systems; mainly base isolation systems that open a new era in the earthquake resistant structure designs on bearing systems responses on of the reinforced concrete structures. Seismic isolation is earthquake resistant structure design approach based on the principle of reducing the seismic forces transferred from the ground to the structure (Güner,2012).The aim of seismic isolation systems is to ensure that all the displacements are based on the foundations of superstructures and in the presence of damping element, to absorb and damp the earthquake energy. The Ministry of Health has requested the use of the isolator system with Circular 2013/3 hospital building (A Minimum Standards Applied to the Project and Construction Works of Earthquake Isolator Structures).

In addition ,Rules and design criteria of the new seismic isolation buildings in static projects are given in the regulation (TBDY-2018) that came into force for the first time on 01.01.2019. The earthquake behavior of the structure will be examined according to two different types of seismic isolators (Figure 1.) that can be used in the isolation buildings given in Section-14 in the new earthquake regulation (TBDY-2018). Some calculations, graphics and tables used in the modeling of the structure and in the design of the seismic isolators are not included in the TBDY-2018 (Turkish Earthquake Code). Therefore, the ASCE-7-10 (Minimum Design Load for Buildings and Other Constructions) regulation, which is an updated version of the UBC-97 regulation, will be applied when necessary. Seismic isolation is more suitable for short-period structures. Less than 10 floors of reinforced concrete structures, less than 5 floors of steel structures, low rigidity structures are suitable for seismic isolation. With the increase in the height / width ratio of the structure, the increase of the tipping moment increases the possibility of the structure to overturn or collapse. This complicates the use of isolation in very high-rise buildings. Compared to the two different isolators used, the advantages of lead core isolators are wide bed capacity, lead core and elastomeric bearings can be designed as desired. Other advantages are its ability to flow under stresses such as 10Mpa due to shear stress and to be resistant to metal fatigue in repetitive loads. Although the lead core rubber bearing is likely to be damaged during strong earthquakes, the fact that it performs well in some severe earthquakes weakens this possibility. Friction pendulum isolator, due to its design feature, isolator does not break even in case of an earthquake which is larger than the earthquake intensity which is expected to affect the structure. In case of breaking of the rubber bearings during horizontal displacement, there is a need for safety mechanisms called "back up" which will carry the upper structure for this reason (Karakurt,2014). Also , It provides structural optimization due to its two-way capability.





(a) **(b)**

Figure 1. Lead Core Rubber Bearing(a) ; Friction Pendulum Isolation (b) (FEMA-356)

2. ANALYTICAL STUDY

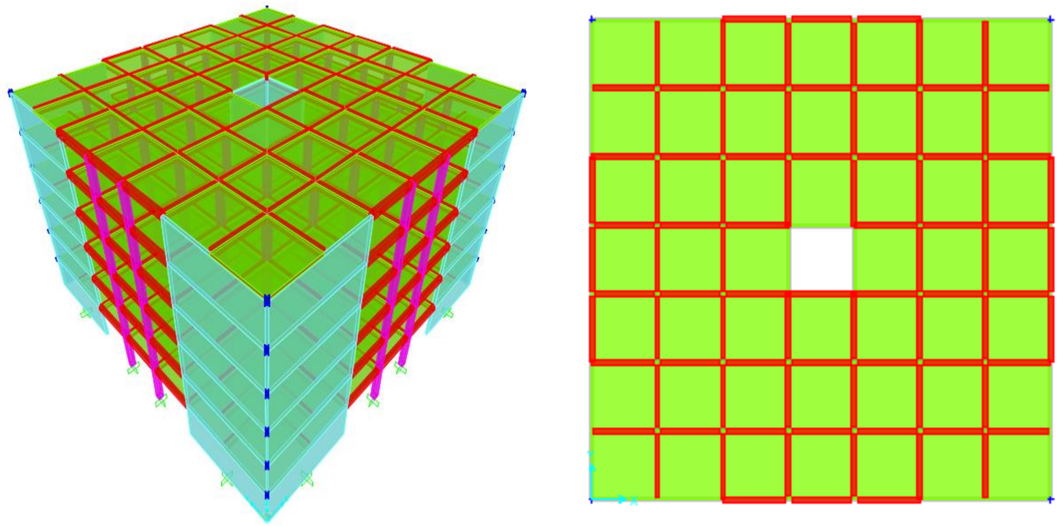
In this study, 6-storey shear wall-frame hospital building was designed and the analysis was performed with SAP2000 computer program. The carrier elements are dimensioned based on the dimensions of TBDY-2019, TS 498-500 regulations and standards. A private health center In Istanbul-Kadikoy with its coordinates was examined within the scope of the study. Turkey earthquake maps interactive web applications (AFAD) earthquake report in (DD-1) for selected local point for the project was established. The earthquake response-spectrum curve at the (DD-1) level was established with the earthquake acceleration values that vary depending on the time given in this report. Kocaeli Earthquake occurring in Istanbul region (1999) earthquake acceleration records were used. These records, and the previously generated response spectrum curve (DD-1) were included and simulated in the SeismoMatch program. These acceleration-time recordings were effected simultaneously in both north-south and east-west directions. Buildings are designed as 28x28 m plan dimensions, 7 spans in X direction and 7 spans in Y direction.

Tablo 1. Modal Parameters of 6-Storey Building According to (TBDY-2018)

Propertys	Symbol	Unıt	6-Storey Building
Dead Load (Uniform Area)	G	KN/m^2	6
Live Load (Uniform Area)	Q	KN/m^2	5
Live Load Participation Coefficient	n	-	0.3
Building Importance Coefficient	I	-	1,5
Bulding User Class (Isolation Design)	BKS	-	1
Building Height Class	BYS	-	5

Earthquake Design Class	DTS	-	1a
Building Weight (Dead+0.3Live)	W	KN	35424
Map Spektral Accelaration (DD-2)	S_{DS}	G	0,79
Design Spektral Accelaration (DD-2)	S_{D1}	G	0,216
Map Spektral Accelaration (DD-1)	S_{DS}	G	1,374
Design Spektral Accelaration (DD-1)	S_{D1}	G	0,383
Isolator Target Active Vibration	T_M	sn	1
Maximum Load On Isolator (1,4G+1,6Q)	P_3	KN	4394,6

While modeling, the beams are 30x45 cm, the columns are 40x40 cm and the shear-wall sections are modeled as 800x20 cm. The building is designed as a soil class (ZA) in the high seismicty region degree earthquake zone. The concrete compressive strength used in the whole structure was considered as C30. The thickness of the slab is considered as 15 cm (Figure 2). No reduction in seismic forces has been made in order to see the effects of seismic isolators on the structure earthquake performance thus, R = 7 was taken for pre-design of (DD-2) and R = 1 for (DD-1) isolator design. Columns and beams, shear walls are assigned as rod elements. The weight and mass of the infinite rigid beam are neglected.



(a) **(b)**

Figure 2. Three-dimensional model in three-dimensional(a) and x-y plane(b) view (6-Storey)

2.1. Nonlinear Analysis in Time Definition

The earthquake acceleration records that we will use consist of the data of East-West and North-South direction recorded in Düzce Meteorology Station of Kocaeli Earthquake (1999). Turkish earthquake regulation (TBDY-2018), the seismic hazard in a field is defined by the spectrum of design acceleration. It is allowed to use acceleration records compatible with the design acceleration spectrum in linear elastic or nonlinear non-elastic earthquakes calculations in the time domain of structures. Actual earthquake recordings have been chosen to meet the conditions specified in the regulations and simulated to match the design acceleration spectrum. SeismoMatch program was used for this simulation (Figure 3), (Figure 4). Using these records, non-linear analysis was performed in the time domain in the Sap2000 program.

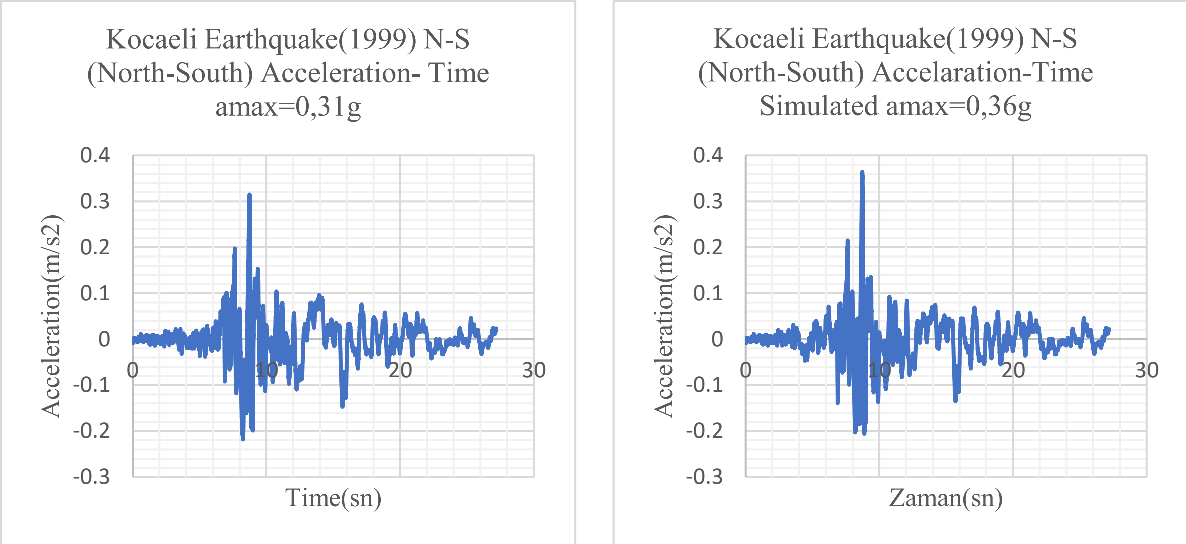


Figure 3. Kocaeli(1999) earthquake N-S, N-S (Simulated) directional acceleration-time graphs

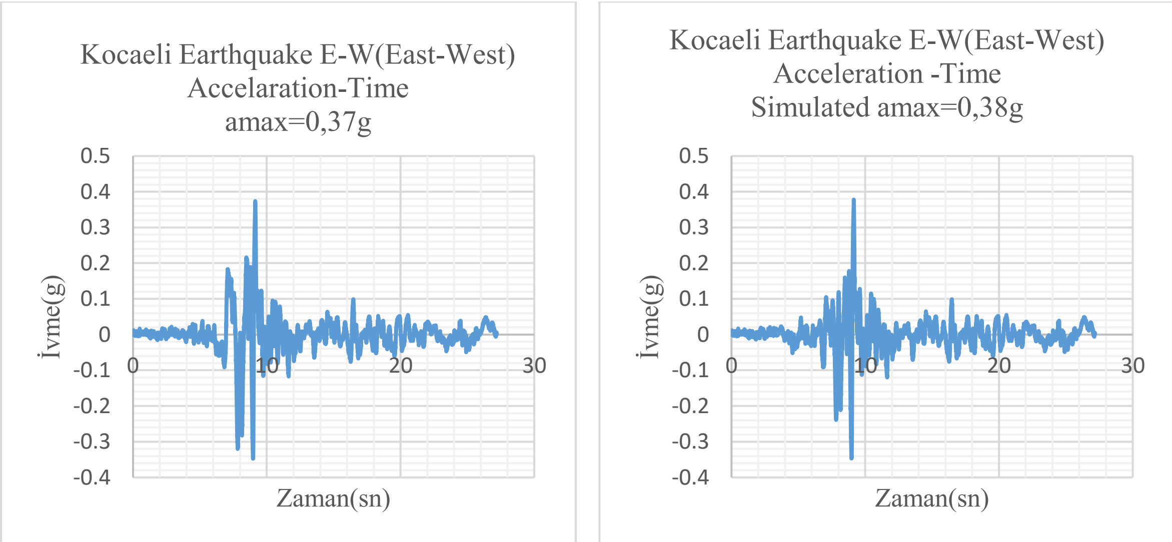


Figure 4. Kocaeli(1999) earthquake E-W, E-W (Simulated) directional acceleration-time graphs

2.2. Mechanical Parameters of Seismic Isolators

Mechanical parameters have been determined by using TBDY-2019 and ASCE-7-10 regulations. Isolator parameters obtained according to the regulations are given in Table 2.1 and Table 2.2 LINK elements have been defined under each column and shear-wall in the curtain-frame system. It is assumed that the seismic-isolation structure shows linear behavior under the lateral and vertical forces .
Since the rigidity of the structure is more rigid compared to the isolation system despite the necessity of nonlinear analysis, the structure is solved by linear elastic analyzes to simplify the solution and realistic data is obtained. (Doğru, 2014).

Table 2.1. Detection of lead core rubber seismic isolator mechanic parameters (6KHKÇKI)

Parameter	Symbol	Unit	6-Storey Building
Elastic stiffness	K_1	KN/m	807000,35
Secondary Stiffness / Elastic Stiffness	K_2/K_1	-	0,01
Effective Yield Strength (Characteristic)	Fy	KN	395,51

Effective Stiffness	Keff	KN/m	9402,81
Total of Effective Stiffness	∑Keff	KN/m	469343,31
Effective Damping of The Systems	§	-	0,1
Vertical Stiffness	K_v	KN/m	3461743,25

Table 2.2. Detection of friction pendulum seismic isolator mechanic parameters(6KMHSSI)

Parameter	Symbol	Unit	6-Storey Building
Elastic stiffness	K_1	KN/m	66255,1
Secondary Stiffness / Elastic Stiffness	K_2/K_1	-	0,10
Effective Yield Strength (Characteristic)	Fy	KN	345,70
Effective Stiffness	Keff	KN/m	7860,16
Total of Effective Stiffness	∑Keff	KN/m	400868,27
Effective Damping of The Systems	§	-	0,1
Vertical Stiffness	K_v	KN/m	11258027

3.RESEARCH FINDINGS

3.1. Comparison of Natural Vibration Periods of the Buildings

The first, second and third mode natural vibration periods obtained in the analysis of fixed based and systems modeled with seismic isolators are given in Table 3.1.When the structure is designed as a seismic isolator, the natural period of vibration increases by 3-4 times compared to the classical(fixed base dual system) method.

Table 3. Natural Vibration Periyod of 6-Storey building with Different Types of Isolations and Fixed Base System

Storey	Mod	Fixed Base Dual System Period(sn)	Lead Core Rubber Bearing Period(sn)	Friction Pendulum İsolation System Period(sn)
6	1	0,32	1,21	1,33
6	2	0,32	1,2	1,33
6	3	0,18	1	1,13

3.2. Comparison of Drift Ratio and Accelaration Values of the Models

After the necessary information and records were entered in the Sap2000 program, dynamic analysis was performed in the time domain according to the EQ (Kocaeli) -1999 earthquake record. The structure gives more realistic results when nonlinear modal analysis is performed in the time domain. The results of the points in the same section and direction were compared with the reference point. The results were compared according to the x-z plane and the reference point determined in the y = 8 m section.

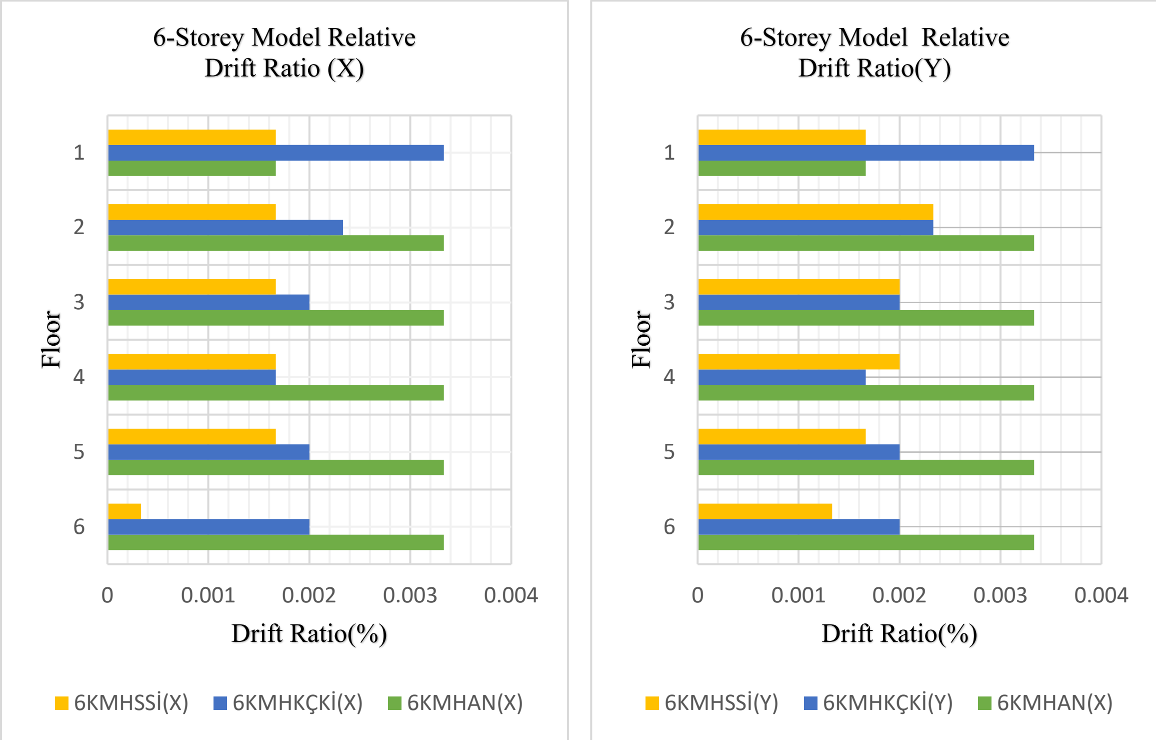


Figure 5. Comparison of relative drift ratio(%) of 6-storey hospital buildings in two different directions (X, Y)

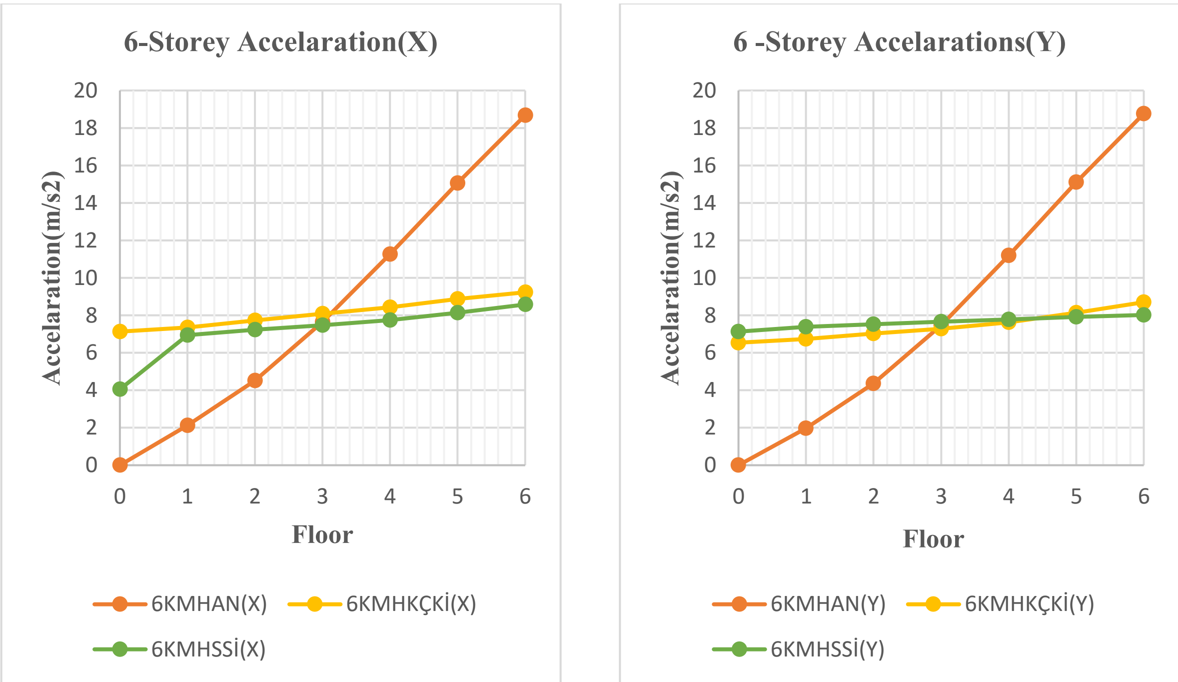


Figure 6. Comparison of the acceleration values of the 6-storey hospital buildings in two different directions (X, Y)

4. CONCLUSION

- As seen in (Table 3), the natural vibration period of building with friction pendulum isolator (6KMHSSI) is bigger than the building with lead core rubber isolator (6KMHÇKI) and building with fixed base dual. It is seen that natural vibration period values in buildings applied seismic isolator have reached to very big numbers (3.5 times) and become safer against earthquake forces.

- 6-Storey hospital building compared in terms of acceleration values in horizontal direction (Figure 5), building with friction pendulum isolator (6KMHSSI) and lead core rubber isolator (6KMHKÇI) has smaller acceleration value than fixed dual system
- 6-Storey hospital building compared in terms of relative drift ratio values(%) (Figure 6), building with friction pendulum isolator (6KMHSSI) and lead core rubber isolator (6KMHKÇI) has smaller drift ratio (%) value than fixed dual system.
- In seismic isolation systems; internal forces, relative drift ratio(%) and acceleration of the floor were decreased, but the natural vibration period was increased according to this study

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**This study was produced from the master thesis (The Effect of Different Seismic Isolator Types and Floor Number to Earthquake Behavior on Multi-Storey Reinforced Concrete Structures) while preparing the the first author and advisor of the second author **