Wireless Network Based Automated Table to Detect Seismic Activity for Kindergarten Pupils

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***Abstract*— Numerous studies show that more than 300,000,000 school children are greatly exposed to danger during an earthquake because of insufficient school construction. In case of an earthquake, pupils are instructed to take refuge under their tables. In that way, school children are still not safe just being under their tables since it is not earthquake-proof which can turn to lethal traps. In this study, a technology was developed and it focuses on enhancing the actual table to be a wireless-based earthquake-proof automated table for Kindergarten pupils. Quality materials and tough development are prioritized to make it strong. Once an earthquake is detected, it automatically transforms into its protective form and alerts the authority. The table comes with storage for food, water and other necessary supplies. Results showed that after a number of trials, the system established a 100-second response time. The automated table is sturdy enough to withstand falling debris as shown on the results of simulation. Stakeholders evaluated the technology Excellent Quality (EQ) in design and aesthetics, usability, system functionality and mechanism functionality. In conclusion, the developed technology is an effective tool for disaster preparedness and disaster risk reduction. This is a new step to give further innovations and ideas to Earthquake Engineering.**

Keywords—earthquake, automated table, Kindergarten, disaster preparedness, disaster risk reduction

I. Introduction

Thousands of tremors are a common occurrence in our everyday lives. These are smaller tremors that often go unnoticed by most people. Although we usually consider the ground to be solid and stable, the earth is, in fact, constantly shifting under our feet [1]. Major earthquakes, when it strikes, it may result in a massive destruction. It can strike suddenly and without a warning.

An earthquake is a calamity that cannot be predicted, it happens when two tectonic plates under the Earth`s surface collides, resulting in a sudden release of energy in the Earth`s crust [2]. To predict an earthquake is impossible, but a scientist can get the interval between earthquake occurrences. For the last 1,400 years in a West Valley Fault, it has been detected that four major earthquakes have occurred in 400 to 500 years of interval. And in the year 1658, the last major earthquake that comes originally from that fault was recorded, which means sooner or later in our lifetime a big movement of the fault may happen again [3]. In the Philippines, there is the Philippine Institute of Volcanology and Seismology (PHIVOLCS), a service institute of the Department of Science and Technology (DOST) that is responsible to mitigate the disasters that may arise from volcanic eruptions, earthquakes, tsunami and other related geotectonic phenomena. Experts announced that in our lifetime, there is a threat of a great earthquake that is called The Big One [4].

Earthquake fatalities and injuries are common due to structures falling on people. The 2010 Haiti earthquake with a magnitude 7 have almost 200,000 deaths that are caused by the collapse of poorly-constructed buildings [5]. There are still many buildings that are not constructed to hold out an earthquake. So, the Earthquake Country Alliance told that during earthquake, best chance of protection is by doing the Drop, Cover and Hold On. This is the general advice for everyone, especially school children. Dropping, covering your head and your body by crawling under a table offers greater protection in most situations [6]. But existing tables are not sturdy to withstand intense weight loads hence giving greater risks on children's safety.

When it comes to natural disasters like an earthquake, children are in many ways vulnerable or have greater exposure to safety hazards and have specific needs in emergency situations. They have higher casualty rates compared to adults since they are not yet mentally and physically developed thus leading to limited actions. Since children are dependent on adults, they will face greater risks when they are left alone.

At any given time, more than 300,000,000 school children worldwide is facing impending danger because their schools are not built to withstand an earthquake [7]. It's a common practice for school children, especially Kindergarten pupils to crawl under the tables when an earthquake strikes, but a standard table cannot withstand tons of debris. It can be a deadly place to be trapped when the legs of the table snapped when the ceiling falls thereon. Typically, the ceiling won't break while falling and hence will fall in large pieces. A standard table doesn't have that enough weight bearing capability, thus will only cause massive casualties.

II. Related Literature

Arthur Brutter and Ido Bruno designed an earthquake-proof table to address the weakness of the school desks during earthquake and to protect students from falling debris [7]. The table is made up of rectangular metal and wood for the tabletop. It can withstand vertical impacts. The table designed by Bruno and Brutter is lightweight enough that it can be easily lifted and moved by the pupils at a certain distance.

A study that is made in the Philippines, the LAMESA Project – Life Saving Automated "MESA" to Endure Seismic Activity is a life-saving Kindergarten school desk [8]. The table is composed of a structural support frame. Said support frame have top and middle portion. Said top portion is a mid-separated tabletop having a plurality of corner legs and adjustable center legs with synchronous lift function to form a triangular shape for debris impact reduction actuated by a plurality of actuators while said middle portion having a main controller unit further comprising an accelerometer that detects seismic activity. It also comes with an Arduino microcontroller triggering the plurality of actuators, and a separate storage area for food and water. Characterized in that, a separate accelerometer fixedly attached to the classroom wall, triggering the emergency alarm synchronous with the plurality of actuators lifting the mid separated tabletop and an LCD monitor displaying the earthquake's intensity and an evacuation message.

III. Methodology

A. Hardware Design

The automated table has 5 major parts which are the tabletop, tabletop frame, telescopic leg, linear actuator and the bottom frame. The tabletop is made up of galvanized iron sheet. The edges are rounded and its surfaces are well polished to prevent accidental cuts and bruises to the Kindergarten pupils. The proponents used mild steel for the frame because of its high durability and stability due to low amount of carbon, high resistance to breakage, high tensile and impact strength, malleability and machinability [9]. The proponents also designed the corner legs to have the adjustable function with the help of the linear actuator that lowers the legs into its protective form to cause the debris to slide down. Also, the leg extension can lock in place with the help of the limit switch. The midsection is designed for supply storage for food, water and other necessities for Kindergarten pupils in case of entrapment.

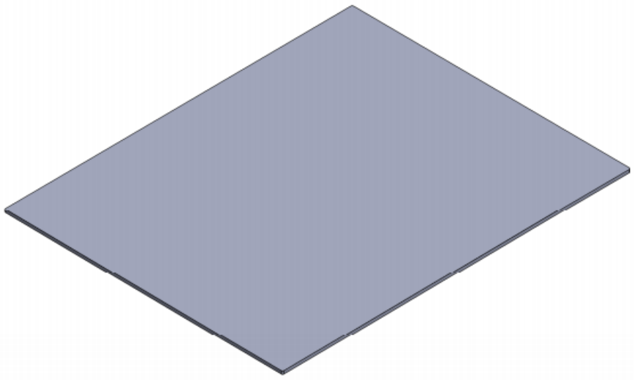


Fig 1. Tabletop

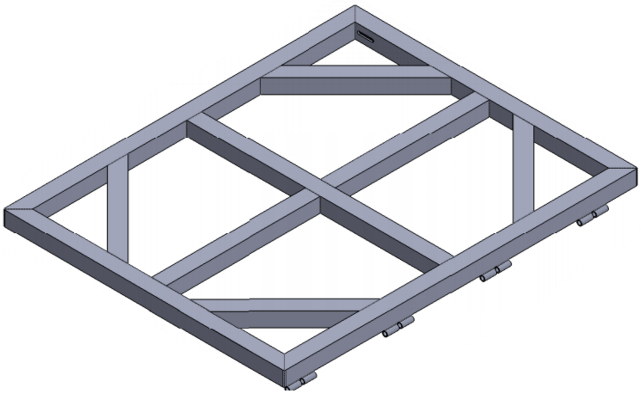


Fig 2. Tabletop Frame

Fig 3. Telescopic Leg

Fig 4. Linear Actuator

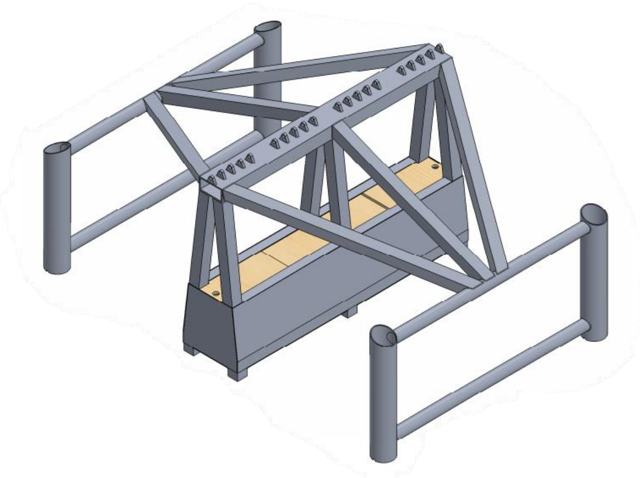


Fig 5. Bottom Frame

Figure 1-5 shows the major parts of the automated table: tabletop, tabletop frame, telescopic leg, linear actuator and bottom frame.

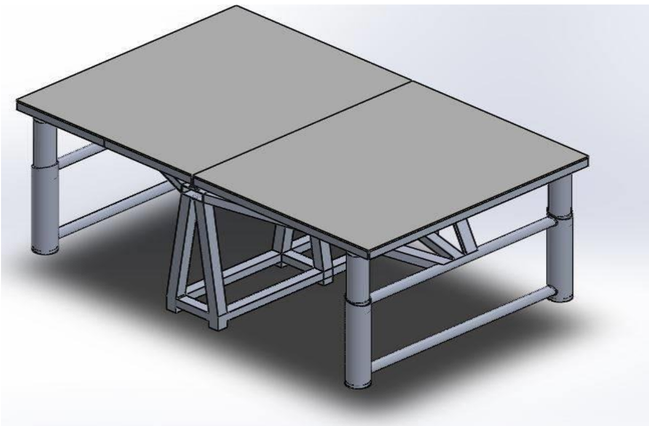


Fig 6. Table Main Form

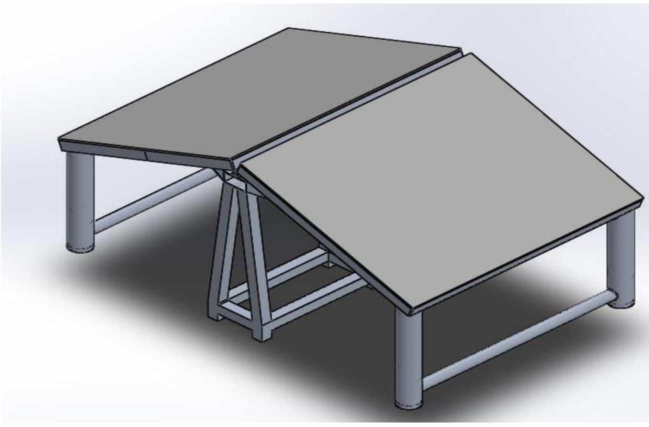


Fig 7. Table Protective Form

Figure 6 and 7 shows the different phases the table undergoes. It shows the isometric view of the table in its main and protective form.

Fig 8. Kindergarten pupil measurements

Fig 9. Kindergarten Pupils Covering Under the Table

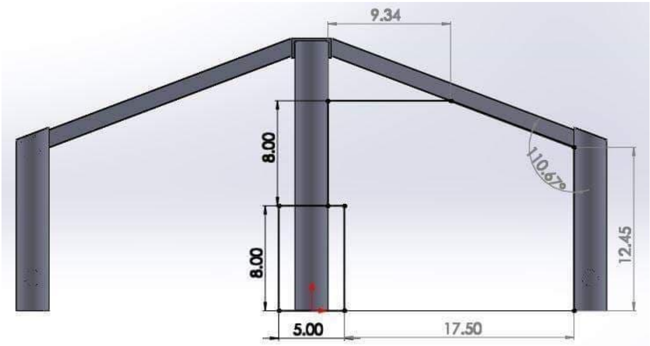


Fig 10. Table Structure Dimensions

Figure 8 and 9 shows the corresponding height, width and the proper sitting position of the Kindergarten pupils under the table. The proponents adopted these measurements to the table dimensions for it to be suited for Kindergarten pupils. Figure 10 shows the 2-dimensional structure of the table. In this figure, the height and width measurements are indicated, along with supply storage in the middle.

B. *Software Design*

Figure 11 shows the block diagram of the automated table. The system compromised of four tri-axis accelerometers, base station, alarm system and GSM module. Inputs of the system are the seismic activities which will be sensed by the four ADXL335 accelerometers. NRF24LO1 transceiver serves as the link of communication for the whole system. Based on the movements, the accelerometer will produce three sensor readings which are the x, y and z values. These values will be fed to the Arduino Nano, which will serve as the central controller of the system. The Microcontroller will then store these values and will determine if it is an earthquake or not. Once it is confirmed, the system will trigger the outputs simultaneously, which are the motors in the table, alarm system and the GSM module. The system will control the solenoid to transform the table from its main form into its protective form with the help of the limit switch. Also, the system will activate the alarm and will send a message to the registered number, thereby alerting the authorities and people nearby.

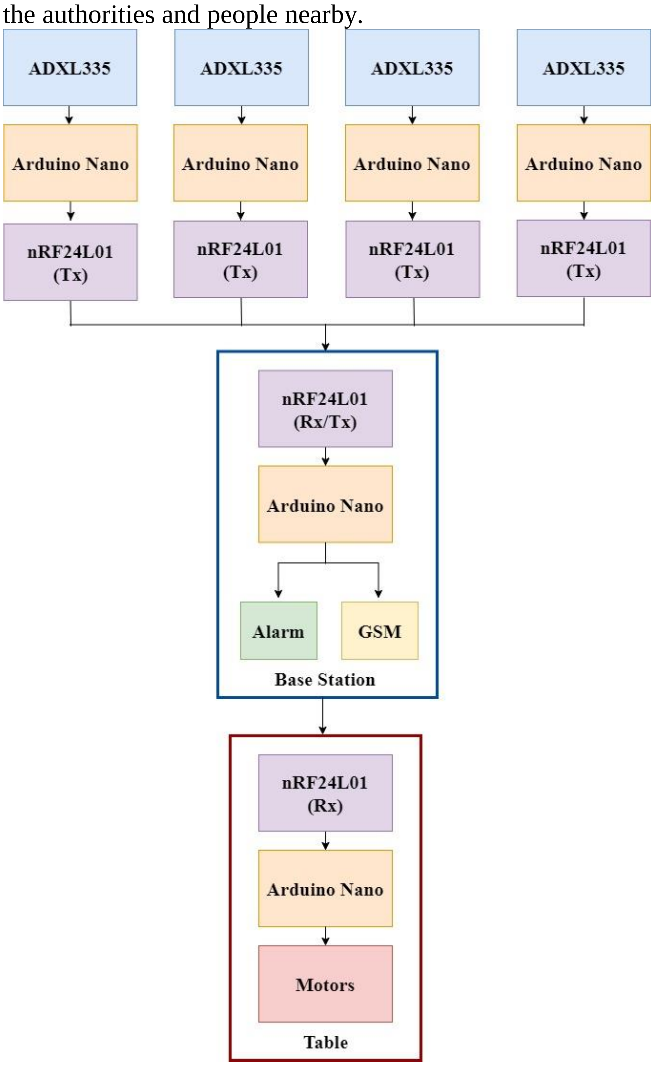
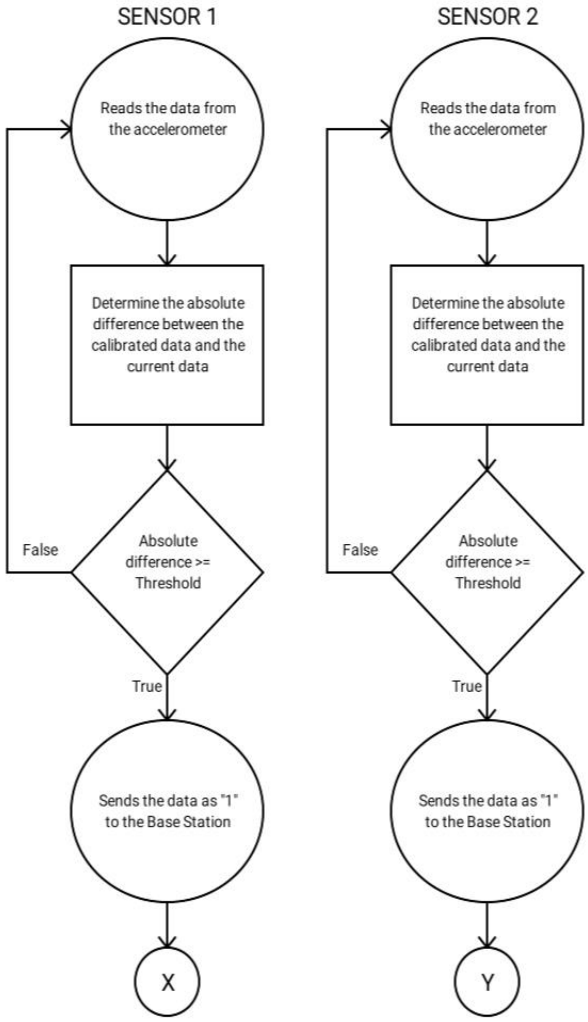


Fig 11. Block Diagram

Figure 12 shows how the system works and the process to get the output. At the beginning of the process, four accelerometers will measure the x, y, z accelerations. After reading the data from the accelerometers, the Arduino will then measure the absolute difference between the calibrated and measured data. If the difference is greater than or equal to the threshold accelerations collected, then it will send a binary 1 at the base station. If the base station receives four binary 1, then the system will categorize it as an earthquake and from then, the automated table will be activated.



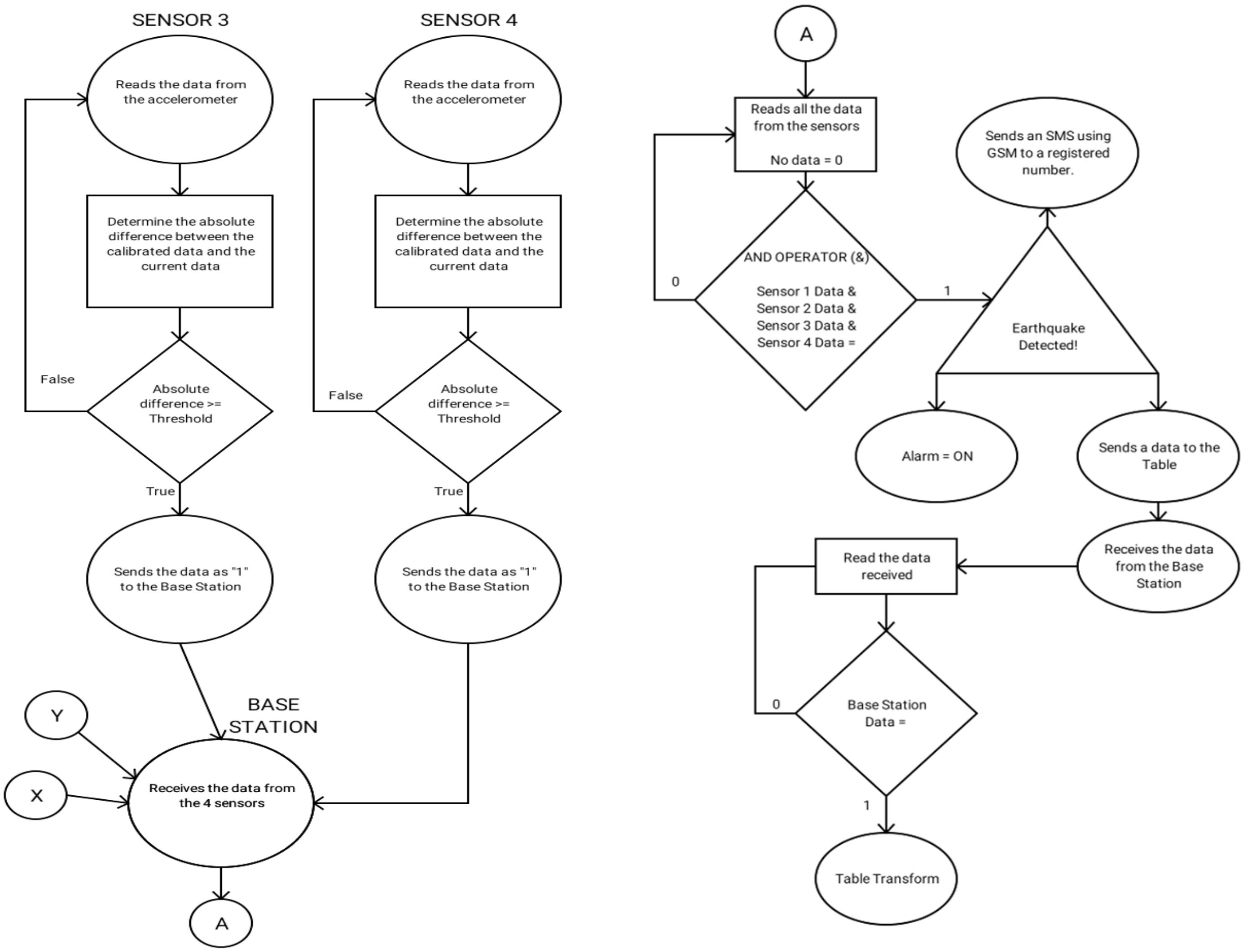


Fig 12. System Flow Chart

C. *Calibration*

Calibration for the accelerometer is done on the MMDA earthquake simulator to get the actual peak gravitational acceleration (PGA) of an earthquake. The proponents measured the peak gravitational acceleration (PGA) for the directions (x, y, z) per intensity level and still condition. Data are shown on Table 1.

Table 1. PGA Averages

INTENSITY	PEAK GRAVITATIONAL ACCELERATION (PGA)		
	x	y	z
STILL	-0.29 to -0.24	-0.25 to -0.22	0.27 to 0.32
4	-0.47 to -0.12	-1.22 to 0.34	-0.32 to 1.11
5	-0.58 to 0.01	-1.28 to 0.41	-0.32 to 1.11
6	-0.61 to 0.22	-1.46 to 0.53	-0.26 to 1.45
7	-0.62 to 0.06	-1.93 to 0.91	-0.38 to 1.28
8	-0.57 to 0.04	-1.51 to 0.56	-0.3 to 1.42

IV. Results and Discussion

A. Functionality Test

The automated table was tested by shaking the sensors to test if it automatically serves its purpose. We tested its functionality randomly 10 times per intensity level. Below is the summary of trials made. Table 2 shows the results of the trials as per intensity level. Intensity 4 shows the least accurate response compared to other intensity levels.

Table 2. Functionality Test

INTENSITY	TRIALS									
	1	2	3	4	5	6	7	8	9	10
4	/	X	/	/	X	X	/	X	/	/
5	/	/	/	/	X	/	/	/	X	/
6	/	/	/	/	/	/	/	/	/	/
7	/	/	/	/	/	/	/	/	/	/
8	/	/	/	/	/	/	/	/	/	/

B. Response Time

The automated table was tested by shaking the sensors to gather its response time. This testing shows the response time of the following parameters: table mechanism, a notification system via GSM and an alarm system.

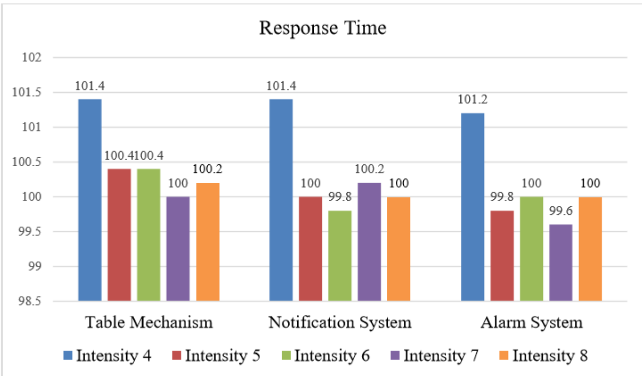


Fig. 13. Response Time Summary

Based on the results in figure 13, intensity 4 shows the longest response time. Furthermore, the fixed response time is about 100 seconds. These seconds provides enough time to shield the students from falling debris. Having a much lesser time will efficiently execute the duck, cover and hold actions of the Kindergarten students to shield themselves from falling debris in case of an earthquake.

C. Dead Load Test

The dead load test is done on SolidWorks Simulation. The development of this technology shows that it is sturdy enough to withstand falling debris through SolidWorks Simulation with dead load up to 60,000 lb_f. The inner and outer legs are the strongest part based on the simulation.

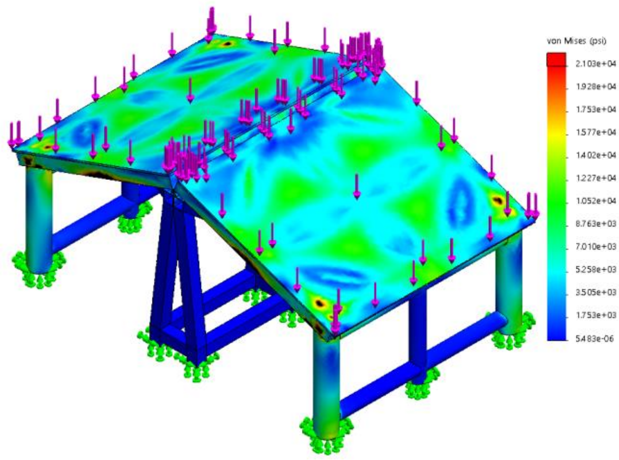


Fig. 14. Von Misses Plot at 60,000 lb_f

D. Evaluation

The proponents sought the help of experts in the field of engineering and disaster management (engineers with specialization in electronics, and mechanical and authorities of MMDA and PHIVOLCS) and stakeholders (Kindergarten teacher, principal, and parents) to evaluate the automated table on the following criteria: Design and Aesthetics, Usability, Mechanism Functionality and System Functionality. The assessment of experts and stakeholders on the automated table was shown on the table below.

Table 3. Assessment of Experts and Stakeholders

	Expert's Rating				Stakeholder's Rating				
Indicators	**A**	**B**	**C**	**D**	**Principal**	**Teacher**	**Parent 1**	**Parent 2**	**Parent 3**
Design and Aesthetics	-	-	-	-	4	5	5	5	5
Usability	-	-	-	-	5	5	5	5	5
Mechanism Functionality	-	-	-	-	5	5	5	5	5
System Functionality	-	-	-	-	5	5	5	5	5

Overall, stakeholders rated the automated table Excellent Quality (EQ) in terms of design and aesthetics, usability, mechanism functionality and system functionality. The stakeholders assessed that the automated table possesses all the indicators and observed just minor problems.

V. Conclusion

The construction of a table with an advanced technological approach is an effective tool for disaster preparedness and disaster risk reduction. The development of this technology shows that it is sturdy enough to withstand falling debris through SolidWorks Simulation with dead load up to 60,000

lb_f. The inner and outer legs are the strongest part based on the simulation. In terms of the automated system, the technology has the capabilities to identify whether a movement is an earthquake or not. Considering the wireless communication, the sensors and transceivers can gather, transmit and receive accelerations accurately. Based on the gathered data, the system established a 100-second fixed response time in terms of table mechanism, notification system and alarm system. This is sufficient to keep Kindergarten pupils safe under the table. It is also economically designed having affordable, but durable characteristics as evident to the feedbacks obtained. Overall, the automated table can provide optimal protection to Kindergarten pupils in case an earthquake strikes.

VI. Acknowledgment

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VII. References

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