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ROCK-FALL TYPES AND ITS SIMULATION USING BLENDER SOFTWARE

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AHMAD G. KHOSHNAW

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ROCK-FALL TYPES AND ITS SIMULATION USING BLENDER SOFTWARE

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In

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Supervisor

Prof. Dr. Hanifi Çanakci

By

Ahmad G. Khoshnaw

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Name of the Student : Ahmad G. KHOSHNAW

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Approval of the Graduate School of Natural and Applied Sciences

Prof. Dr. A. Necmeddin YAZICI
Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science.

Prof.Dr. Hanifi ÇANAKCI

Head of Department

This is to certify that we have read this thesis and that in our consensus/majority opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

Prof.Dr. Hanifi ÇANAKCI
Supervisor

Examining Committee Members:	Signature
Prof.Dr. Hanifi ÇANAKCI	………………………..
Assoc.Prof.Dr. HAMZA GÜLLÜ	………………………..
Asst.Prof.Dr. Mehmet SÖYLEMEZ	………………………..

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Ahmad G. KHOSHNAW

ABSTRACT

ROCK-FALL TYPES AND ITS SIMULATION USING BLENDER SOFTWARE

KHOSHNAW, Ahmad G.
M.Sc. in Civil Engineering
Supervisor: Prof. Dr. Hanifi ÇANAKCI
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Blender is a software used in the film and computer games industries to realistically animate a physical system and produce 2D or 3D animation films. In this paper it is shown that media can be faithfully modeled using a rigid body physics, Rock falling and soil sliding are issues confusing the designers in selecting the alternative roots of roads due to miss availability of exact predicts. The animation program is used to simulate a rock fall model and analyze it by statistical program to evaluate the results and finding the rate of confidence between them. Two types of materials (Wood and Steel) in Cubic shape and spherical shape were tested in the laboratory as two parameters on fixed side slope made of wood, which it has one stage in the mid-distance the motion of materials detected by Physic Tracker Software. Results showed that Blender as computer software is perfect for this purpose and there is a relation of (R^2=0.999) between the parameters. This will help the designers and the geotechnical problems in predicting and considering the best solutions before and even during the construction process.

Key Words: Rack falling, BLENDER Software, Simulation, 3D animation and Statistical analysis.

ÖZET

KAYA GÜZ TİPLERİ VE BLENDER YAZILIMI KULLANILAN SİMÜLASYONU

KHOSHNAW, Ahmad G.
Yüksek Lisans Tezi, İnşaat Mühendisliği
Danışman: Prof. Dr. Hanifi ÇANAKCI
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57 sayfa

Blender, film ve bilgisayar oyunları endüstrisinde fiziksel bir sistemi gerçekçi biçimde canlandırmak, 2D veya 3D animasyon filmler üretmek için kullanılan bir yazılımdır. Bu makalede, medyanın katı bir vücut fiziği kullanılarak güvenilir bir şekilde modellenebileceği gösterilmiştir. Kaya düşmesi ve toprak kayması, tasarımcılar için kesin tahminlerin bulunmaması nedeniyle alternatif yolların bulunmasında kafa karıştırıcı sorunlardır. Animasyon programı, bir kaya düşmesi modelini simüle etmek, sonuçları değerlendirmek ve aralarındaki güven oranını bulmak için istatistiksel programla analiz etmek için kullanılmıştır. Fizik İzleyici Yazılımı tarafından tespit edilen malzemelerin orta mesafesinde bir aşaması olan tahtadan sabit yan eğimde iki parametre olarak Kübik ve küre şeklinde iki tür malzeme (Ahşap ve Çelik) test edilmiştir. Sonuçlar, bilgisayar yazılımı olarak Blender'ın bu amaç için mükemmel olduğunu ve parametreler arasında bir ilişki olduğunu (R^2= 0,999) göstermiştir. Bu, tasarımcılara jeoteknik sorunlarda inşaat süreci öncesi en iyi çözümleri tahmin etmede ve bu tahminleri göz önünde bulundurmada yardımcı olacaktır.

Anahtar Kelimeler: Düşme, BLENDER Yazılımı, Simülasyon, 3D animasyon ve İstatistiksel analiz.

''Dedicated to my great family''

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LIST OF ABBREVIATIONS

SPSS	Statistical Package for the Social Sciences
DDA	Digital Directivity Analysis
CCD	Charged Coupled Device
2DLM	Two Dimension layered materials
3DRB	Third Down Running Back
COR	Coefficient of Restitution
OSP	Open Source Physics

CHAPTER I

INTRODUCTION

1.1 General

In mountainous areas, highways, railways and power generation facilities, and infrastructure such as houses and apartment buildings may be exposed to hazards such as rockfall and landslides, which may consequence in economic loss in arrears to service interruption, equipment and structural damage and loss. Rockfall is a natural hazard similar to storms, floods, volcanic eruptions and earthquakes etc. more specific definition would be that it's a type of mass movement or mass wasting, The term encompasses a series of gravity-induced rock downhill transport (soil, sediment and debris), snow and ice (Marshak, 2011), the same as land landslides (S.Evany Nithya and P. Rajesh Prasanna 2010) downward effort of soil, remains or rock, caused by unusual grounds, vibrations, coverage of rock cover, amputation of lateral supports, changes in WC (water content) of rocks or soils, drainage blockages, etc. Each year, thousands of people around the world have lost their lives in landslides and rockfalls generally with geological disasters. However, damage to infrastructure or directly affected people can be severe and has serious consequences. It is often seen as a harmful event. Established on strict hazard and risk administration approaches, it is important to provide the best protection (A. Volkwein et al., 2011).

Rock falling phenomena is the important issues to be study for designing roads especially in mountain areas. This phenomena influencing the alternatives in selecting the alignment of the different types of highways. Mountains, Hills and all kinds of high or elevated locations were naturally established and composited. Material types and layer conditions vary by location. Therefore; their stability and strength will depend on the geological activity taking place at each location. Nature Freezing and thawing, mass of composite materials and saturation rate of a location are factors to identify types, size and nature of the failures or rock falls for any location.

In civil engineering, the main sectors dealing with landslides or rockfalls are highways, pipelines, sewers and irrigation channels, and later residential and commercial buildings. Figure 1.1 shows an example of the consequences of rockfalls with a volume of about 80 cubic meter from a height of 350 meter that shattered an unreinforced concrete wall and caused severe traffic delays.

Figure 1.1 Rock fall that blocked highway

To predict rockfall trajectories and design protection measures, (C. Wendeler et al., 2017) rock fall simulations are necessary based on the latest findings. In recent years, Considerable progress has been made in these areas to improve the quality and structural design concepts of simulation results in order to protect them with different types of computer software applications.

In 1988, Ton Roosendaal co-founded the Dutch animatronics studio Neo Geo. This studio rapidly come to be the major 3D animation room in the Netherlands. Within NeoGeo, Ton is in charge for art direction and internal software expansion. After suspicious attention, categorical to revision the present internal 3D toolset from scratch. In 1995, this modification activated and was destined to come to be a 3D software tool. It was called BLENDER software, and Blender is a free open source 3D authoring group. It supports the entire 3D pipeline formation, assembly, animation, simulation, rendering, compositing and motion tracking, and even video editing and game creation (Foundation Blender, 2019).

1.2 Objectives

In this study, a simulation between (BLENDER) computer program and the laboratory rockfall tested to predict the opportunities and the disasters that occur during different types of rockfalls when falling from side slopes especially in the highways. For this purpose the direct problems should be addressed to solve the parameters which effect the physical motion of particles through computer programing software and environment control. A model has designed in the laboratory and constructed from wood material, two types of materials wood and steel considered for test the rockfall on model as highways side slopes with two shapes cubic and spherical, then the movement of falling materials detected by a software called Physic Tracker and statistically analyzed by IBM SPSS software.

1.3 Thesis Organization

The project has been organized into five chapters. The second chapter consists of a literature review on geotechnical problems of geological hazards for rock falls that have solutions with different computerized software applications. The third chapter explains methodology and the properties of used materials. The fourth chapter presents the results and discussions that gained from the comparison between whole data by statistical program called as SPSS. At the end chapter five provides the conclusions and recommendations for future problems and researches.

CHAPTER II

LITERATURE REVIEW

2.1. General

Geological disasters are one of several unfavorable geological conditions that can cause loss or loss of property and life. These hazards include sudden and slow phenomena, volcanic eruptions and volcanic ash, phenomena caused by earthquakes and earthquakes such as tsunamis, landslides, lateral displacement of soil on slopes or hillsides, muddy flows of soft soils/wet soils and sediments, rockfalls, landslides and mudslides are major hazards. Figure 2.1 shows the example of Landslide and Rockfall.

Geological hazards are usually assessed by engineering geologists who have received education and training in geography and geo-process interpretation, geo-structure interactions, and geological hazard mitigation. Engineering geologists provide advice and design to mitigate geological hazards. Well-trained disaster mitigation planners also assist local communities in identifying strategies to mitigate the impact of such disasters and develop plans to implement them.

Geological hazards can be avoided by resettlement, and the stability of the slope can be improved by constructing retaining walls. Techniques such as mud walls, shear pins, back connections, soil nails or soil anchors and ground pillars, coastlines and streams can be used for retaining walls. Using revetment and riprap to prevent erosion, the soil or rock itself can be improved by strong compaction, grouting or concrete and mechanically stabilized soil. Other justification systems include deep bases, tunnels, outward and sub-drainage structures and other events. Planning measures include elimination the development of regulations near hazardous areas and adopting building codes to protect and prevent people from harm.

Figure 2.1 Example of Landslide and Rockfall

Weathering and excavation can affect the rock slope at the same time, and can also affect the weathering through archaeological site. Stress release caused by archaeological site may lead to new fissures in whole rock and expand current gaps (Hack and Price, 1997). This will cause the rock to lose strength and become more deformable (Momeni et al., 2015). Therefore, the safety factor of the rock incline is reduced and then the stability is lost. Landslides, including falling rocks, pose a serious hazard to settlements and transport routes in highland areas (Cruden and Varnes, 1996). Deterministic or probabilistic analysis established on 3D modeling (Guzzetti et al., 2002; Lan et al., 2007; Frattini et al., 2008) is a useful tool for estimating the maximum travel space and associated kinetic energy of rock masses of certain sizes in local and regional scope.

During the construction phase, the possibility of mechanically causing rock fall might be one to two orders of degree greater than normal causes such as increased pore force, freeze-thaw, chemical dilapidation, or origins (Mehran Koleini and Jan Louis Van Rooy, 2011). Even rock slopes that appear to be stable have free rock masses that can easily fall off if concerned.

2.2. Rock fall Phenomena

Rockfall is the movement of rocks from a very steep slope, and the rock continues to move down the slope. This movement can be sliding, rolling, bouncing or falling freely. Figure 2.2 shows the rockfall modes of travel. The term "rockfall" is commonly used to describe various types of ground falls, including single or multiple rock falls, landslides, or other forms of slope example planar slip, wedge, dump, and round.

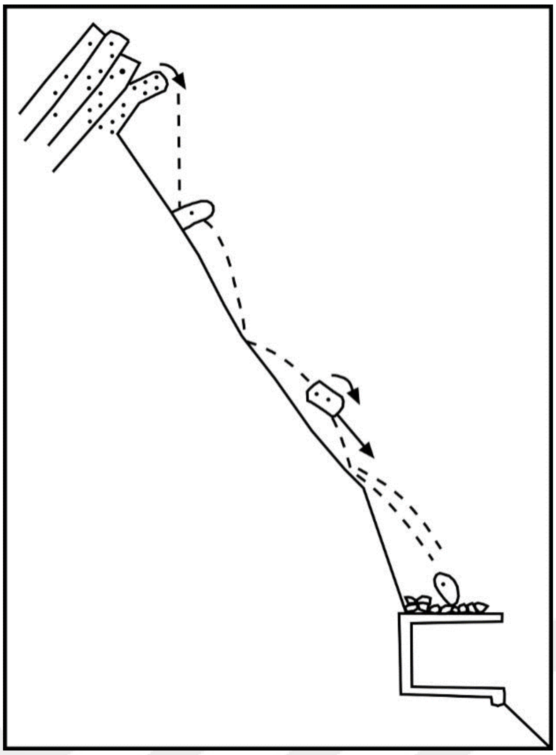


Figure 2.2 Rockfall modes of travel

The leading study about rockfall was carried in 1963 by Arthur M. Ritchie. He renowned that there is a rich need for a means of expecting the stability of substantial on the superficial of a rock cut (Ritchie, 1963).

Geological rockfall hazards result in damage due to disturbances and apparatus harm, as well as damage to operators and hands of these services. As an image of these hazards, Figure 2.3 shows a vehicle that hit a falling rock over the windshield.

In zones with large rainfall, regular freeze-thaw sequences and earthquake actions, the danger of falling rocks is particularly serious, and the risk may be high in areas with high population density. The consistency of the modeling program depends on a comprehensive considerate of influence mechanism and trajectory investigation and provides accurate data on real rockfall to standardize model (Duncan C.Wyllie, 2014).

Figure 2.3 shows a vehicle that hit a falling rock over the windshield.

Indication sorts of falling rocks depend on the mean slope gradient that will transform as falling, bouncing and rolling Figure 2.4 shows the modes of motions. Freefall movement occurs on steep slopes when the angle gradient outstrips 76° (Ritchie, 1963), in diverse field environments this value differs. The wave of the rock regularly converts from bouncing to falling. During freefall of rocks transformation of the middle of rock and turning of the block about its center travels can happen (Azzoni et al., 1995). Air roughness and impact with other falling rocks touch the velocity of a falling rock. Agreeing to (Bozzolo and Pamini, 1986), there is no significant result of air roughness on the measure of the rock.

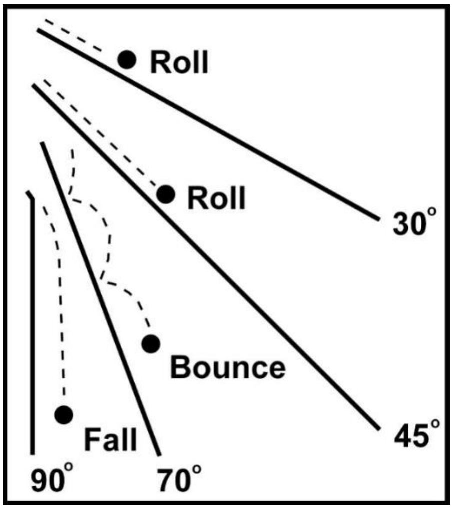


Figure 2.4 shows the modes of rockfall motions.

The Movement at or close to angle exterior causes colliding on the slope surface this is defined as bouncing (Dorren, 2003). Which rocks travel in different surfaces with different speed and motion. When the average slope is less than about 45°, the bounce wave changes to rolling. The turning of the rock is exact wild through the evolution between bouncing and rolling. Additional wave type is sliding. It usually happens in the first and last phases of rockfall. the average angle increases, the sliding rock begins to fall, bounce or roll. If the average angle does not change when sliding, the rock regularly rests because of energy loss due to roughness (Bozzolo and Pamini, 1986).

It is common to divide slopes where rockfalls are active into three sections. The upper area where movement is initiated is often called a release area, release zone, starting zone or source zone (Dorren et al., 2013). The second area is called the transit zone which is the area rockfalls have to traverse before reaching the overlapping third area; the deposition zone (Dorren et al., 2013) Figure 2.5. Rockfalls propagate through the transit zone as specific chunks that don’t affect considerably with each other (Domaas and Grimstad, 2014).

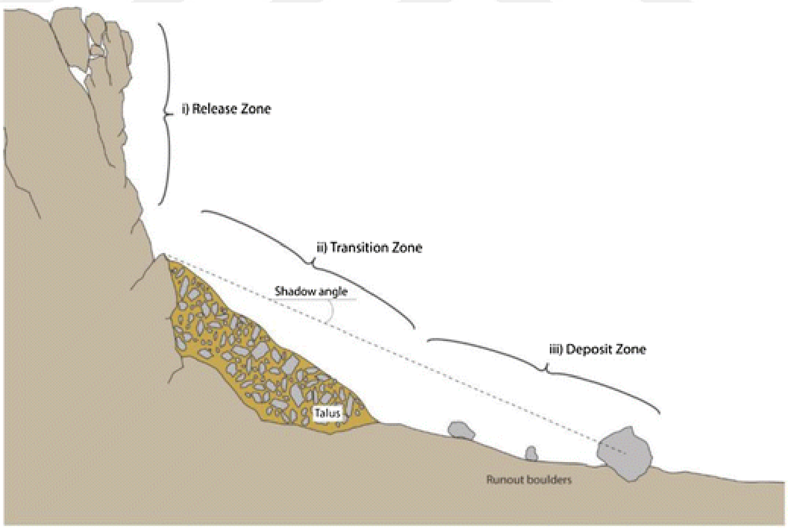


Figure 2.5 Rockfall section zones.

(Ritchie, 1963) Describes this movement as the three key sorts of indication; free fall, rolling and bouncing to rise angle inclination Figure 2.6. Velocity growth rapidly under free fall situations. Once impacting an apparent, a segment of the added kinetic energy is lost and the residual fraction is often called the stones restitution (Domaas and Grimstad, 2014). The rate of the restitution then hinge on slightly of the difficulty for the substrate, changing between 0.3 and 0.7 for effects on unconsolidated resources and 0.5 and 0.9 for effects on bare rock conferring to a study by (Azzoni and De Freitas, 1995). The effects frequently cause the revolution of falling stone (Domaas and Grimstad, 2014). A study by the Japan Road Association found that the rock's revolving energy can reach 40% of the translational energy, although this part is less than 10% in half of the tests (Heidenreich, 2004). Even in flat terrain, this rotational motion can still significantly increase the run length if rock shape allows. Flat and rectangular rocks are not expected to benefit from this rolling motion as much as possible, unless they are continuing sideways, as planar side collisions may cause all rotation to be caught (Domaas and Grimstad, 2014). Rolling is very economical in terms of energy because simply the extreme radius of the rock is at any opinion of connection with the exterior and is subject to roughness (Dorren, 2003). If the continuing block begins to slip, this is corporate in the later stages of the transit zone, and except the average angle variations, the boulders regularly rests due to friction (Bozzolo and Pamini, 1986).

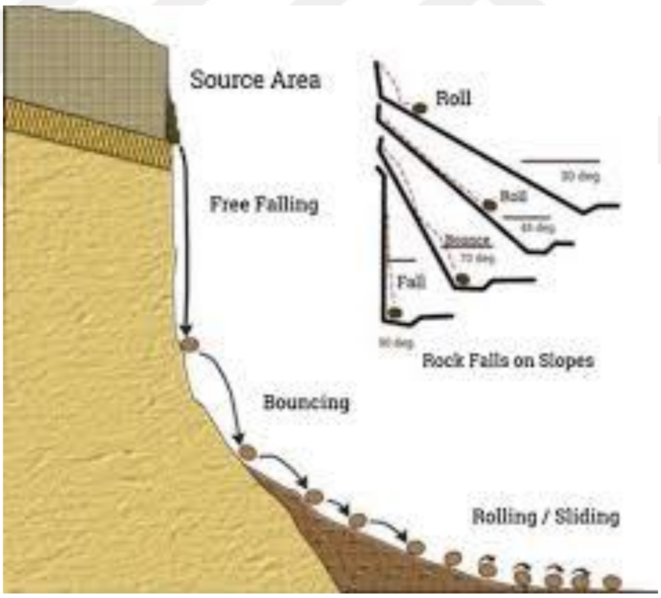


Figure 2.6 Rockfall modes of motion based on slope angles.

The clean surfaces of stiff, unweather rocks are the most hazardous because they do not stop the undertaking of dwindling or rolling rocks to any momentous extent. On the other hand, the talus factual, the screen or pebbles-covered surface absorbs the considerable energy of the falling rock and, in many circumstances, will completely block it. Other reasons, such as the size and shape of the rock boulder, the coefficient of friction of the rock surface, and whether the rock breaks into smaller pieces during impact are less important than the slope geometry and recovery factor (Hoek, E., 2007). Assigning a recovery factor to a material is an empirical method because its value is based only on a particular data set and is problematic for that detail (Agliardi and Crosta, 2003). The true nature of rockfall energy loss is based on angle roughness, angle geotechnical properties such as element size distribution, water content, void index, elastic modulus, boulder figure and dynamics, but these energy loss related factors have not been fully determined, factors It is difficult to determine in time and universe. Therefore, although it is theoretically probable to calculate the location and velocity of the falling rock at any time, it is very complex under actual situations (Agliardi and Crosta, 2003).

The problem of falling rocks, especially remediation activities, is mostly managed on an empirical basis because of the limited understanding of the subject. Today, computers represent a valuable tool for dealing with highly flexible occurrences such as rock fall (Azzoni et al., 1995), which now agrees us to make more sensible and repeatable analyses and obtain more accurate calculations for more effective protection.

2.3. Simulation through Software Applications

Rockfall is one of the main subjects in road adversity anticipation. In order to launch a realistic fall anticipation system, the speed and jump height of the falling rock must be accurately estimated. DDA can evaluate the dynamic movement and distortion of an elastomer of any shape, for example, rigid body movement, rotation, and deformation involving discontinuous rock quantity. The angle and equivalent rockfall are demonstrated as masses of a two-dimensional polygon. This is suitable for evaluating rockfall behavior because large deformations such as landslides, jumps and rockfall rotations can be properly simulated. In order to solve the above shortcomings, a new falling rock analysis method using a non-multi-mass system is proposed. Unambiguously, we categorize the mechanisms of energy loss, express rockfall behavior through field experiments, and introduce analytical parameters to express behavioral parameters. We suggest a simulation technique to accurately define the speed and jump elevation of the falling rock. In the field test, a boulder was thrown on an angle, and the movement of the rock was taken with a CCD camera. Through the analysis of the video image, the factors affecting the rockfall behavior are measured in detail. Figure 2.7 presents the site view of experiment.

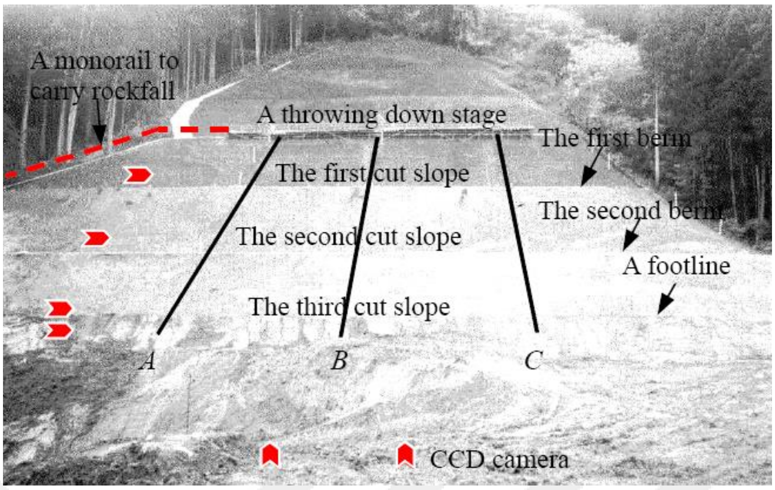


Figure 2.7 Photograph view of experiment.

In these two figures, the geographical location of the cutting slope, route where rockfalls, and position of the camera are displayed in detail.

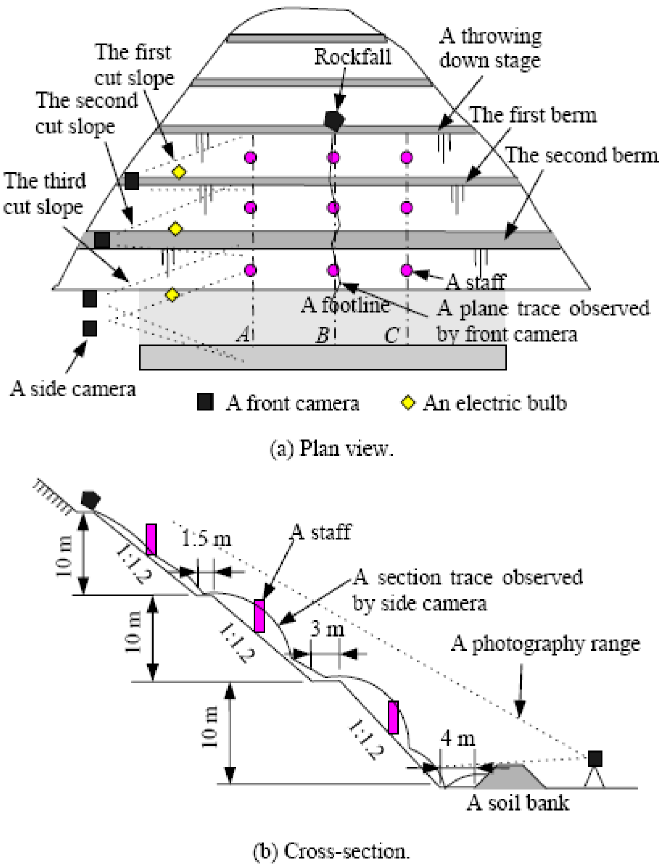


Figure 2.8 Site of experiment and plan section.

The test sites are selected at a cutting ramp having three insignificant periods, each period having a bezel of different width. As shown in Figure 2.8, Six CCD cameras adjusted and worked, four of which were mounted on one side of the slope, recording the cross-section movement of the falling rock, and two mounted in front of the angle to record the vertical movement of the falling rock. Figures 2.9a and b show traces of rockfall along line A in all circumstances, and trajectories provided by frequent testing of minor rockfall along line A. From the examination results, we can appreciate the following features of rockfall (Guichen Ma et al., 2011):

(1) On the first slope, a certain degree of a small jump is observed, but in most cases, the sliding or rotating motion is dominant because the surface unevenness is small. On the other hand, once the rock falls from the cutting slope, only a collision or jump occurs at the bottom.

(2) After colliding with the higher and lower berms, the falling rock showed a large jump. Therefore, we can recognize that the flat surface of the mid-slope has a great effect on the effort of the falling rock. In particular, a flat region can be considered to convert a sliding or rotational motion into a spring or collision motion.

(3) Even if the falling stones are carried out under the similar conditions, that is, the similar boulder, the similar line, and the similar location, the suggestions in the repeated test show a large change. This is considered to be due to the nuances of the riprap conditions, such as the shape of the angle and the abnormality of the shape of the falling rock, which is unescapable in nature, and the cumulative difference in the traces during the falling rock becomes negligible.

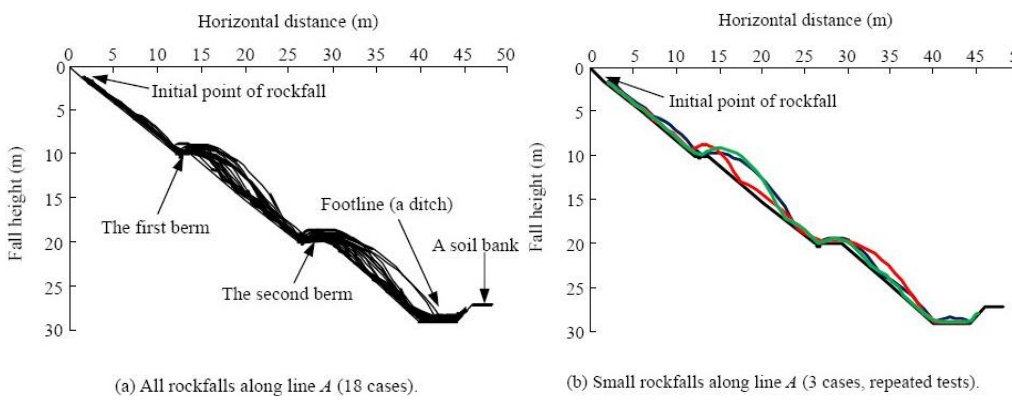


Figure 2.9 (a) and (b) shows the results of rockfall tests in the traces

The Rockfall trajectory field test was conducted at a large open-pit gold mine in Western Australia to calibrate numerical models of rock to provide a realistic simulation of the rock's fall trajectory, not just the input parameters in the literature. A total of 25 individual rock fall trajectory tests were performed at 50°, 60°, 70°, and 80° tilt angles, with multiple tables available for the following travel path diagram 2.7. The trajectory of the field test was simulated using a 2D and 3D rock fall impact model. In the 2DLM and 3DRB models, the observed rock fall trajectory path is modeled in software by adjusting the relevant input parameters, especially the recovery coefficients. The recovery factor is determined by previous design of recognized rock tracks and endpoints from field trials of rock fall trajectories. As expected, harder materials such as countertops have softer materials such as workbench floors that achieve higher recovery factors. Typically rock fill comprising cobbles, gravel and some fines.

The standard slope geometry profile is used to determine possible rock fall trajectories associated with various bench design configurations, including 45°, 60°, and 75° mesa angles, assuming very smooth in 3DRB, and a standard deviation of slope roughness of 2DLM 2°. The width of the table is four meters, five meters, six meters, seven meters, eight meters, nine meters, and ten meters. For the purposes of this article, only the 20 m table height is discussed. Five stacked benches provide stack height or slope height of 100 meters Figure 2.10. Shows the bench model.

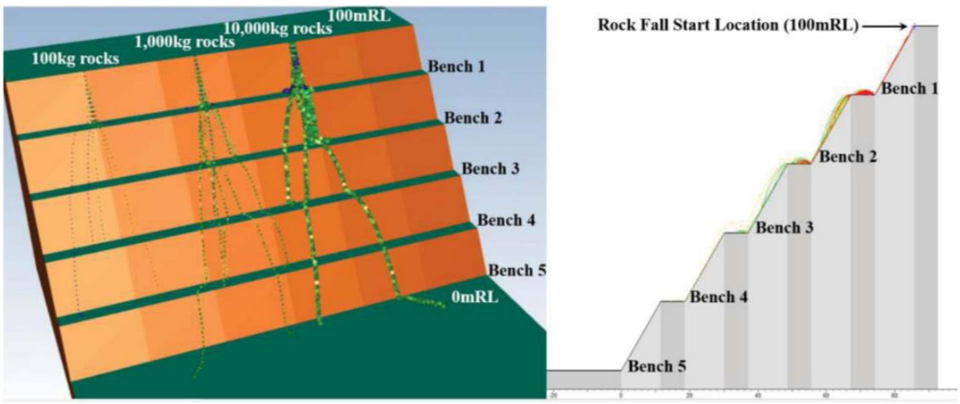


Figure 2.10 Bench model

Using the 2DLM and 3DRB models to simulate the percentage of rock captured on a bench suggests that a narrower bench width may allow a wider bench to capture fewer rocks. Compared to the 3DRB model, the 2DLM model simulations show that capturing rocks on "wider" benches is more "deterministic." The 2DLM results indicate that the improved Ritchie criteria can still accommodate benches up to 20 meters high than other. A steeper mesa angle results in a shorter rockfall trajectory. The 3DRB results are related to historical rockfall and other forms of slope collapse case studies. If only a single rockfall event is used in this historical dataset, the correlation may be better (Neil Bar et al., 2016). Current enhancement in the field of hardware and software technology have run to systems skilled of carrying out simulations connecting many objects even objects with irregular shapes and their interaction in relatively short periods of time. These structures utilize shared measuring loads on the central processing unit and graphics handling unit to make them very fast. Such arrangements are often referred to as physics engines. The physics engine originally developed was used in the evolution of video games, animations and special effects in movies. The special movements of the body and fluid are too complex to be handled manually by animators and game developers and can be physically processed and simulated by the physics engine. For example, they play a significant character in animation and video games in situations involving liquid explosions, cracks or dumps on the surface. As mentioned earlier, physics engines are primarily established for gaming and movie entertainment, however, they are also used by researchers for simulation in industrial engineering.

Bullets are an open basis physics engine accomplished of execution accident discovery, rigid body and soft body dynamics. Bullet has been unified into Blender software to conduct it easier to design the model, analyze and render on a single platform. All simulations were accomplished consuming the Bullet plugin in the Blender software via the rigid body dynamics section. In the solver of the rigid body dynamics module, there is a simulation cycle involving of collision recognition, collision determination and time integration. Collision detection involves result contact pairs between a numbers of objects. At collision resolution unit, the commerce normal force and the friction force and the moment are solved, and then the position and velocity of the object are updated within a specified time span in the time incorporation portion. This circle carry on till the finale of the simulation. The rigid body dynamics solver analyzes the indication of an object in translation and rotation based on the Newton-Eulerian equation. In addition, the joint and contact are processed using the associated constraint/contact equation. Further details on equations and solutions can be found in the literature. To realistically create the geometry of the gravel, a Voronoi-based tessellation was used. According to the use of the system, block angle polyhedra are produced, which are respectable representatives of the actual gravel used in laboratory tests. An optical assessment of the real gravel and simulated gravel geometry is shown in Figures 2.11a and b.

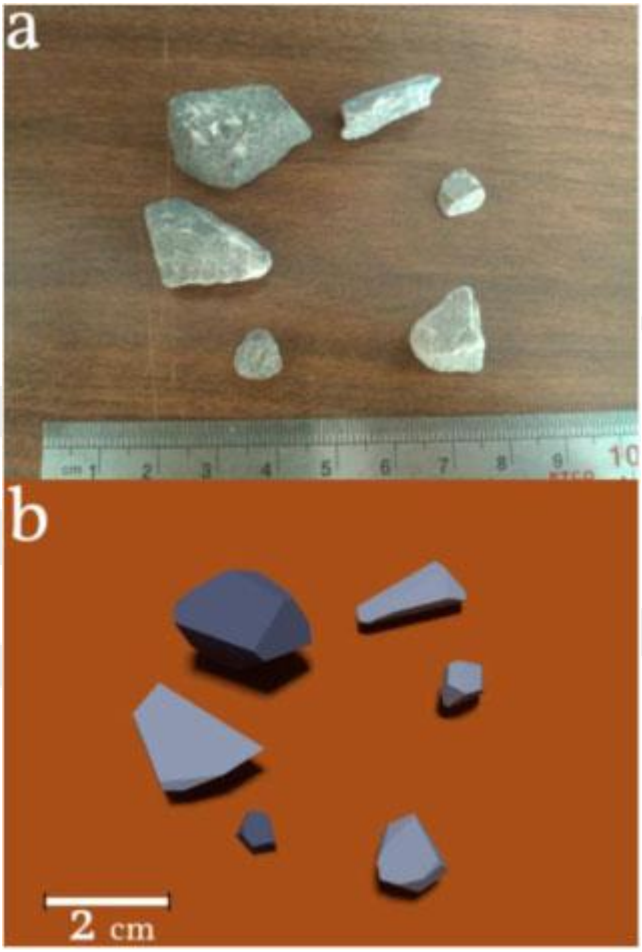


Figure 2.11 (a) Visual comparison of real gravels and (b) simulated ones using the Voronoi tessellation.

The model of the test which prepared by bullet and in lab to be tested is showed in Figure 2.12a and b to be more clearly that describes all part of the objects that gravels will be passed through the funnel prior to pluviation.

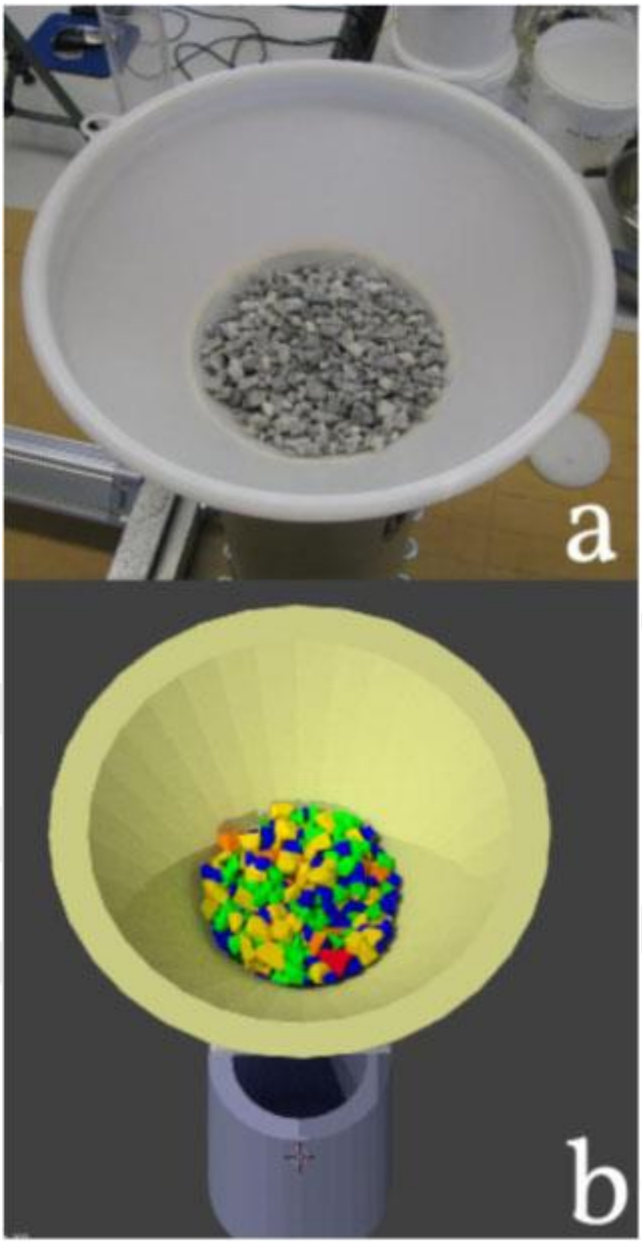


Figure 2.12 (a) Gravels in the lab (b) Gravels in simulation.

The consequences of laboratory experiments and simulations are shown in Figure 2.13. Gray shaded zones indicate the upended height range of the soil in the cylinder used for experimental testing. As declared earlier, a number of tests were conducted to find out this limitation, which show that the height of (Pluviation) increases, the soil height in the cylinder reduces, which is comparable to the (Pluviation) test on sand. For all three configurations, the results of the simulation are indoors the scope of the experimental laboratory outcome. It can be inferred that the bullet can very well simulate the behavior of the gravel. In addition, the results of the simulation were observed to be reproducible for various gravel configurations. (E. Izadi and A. Bezuijen, 2015).

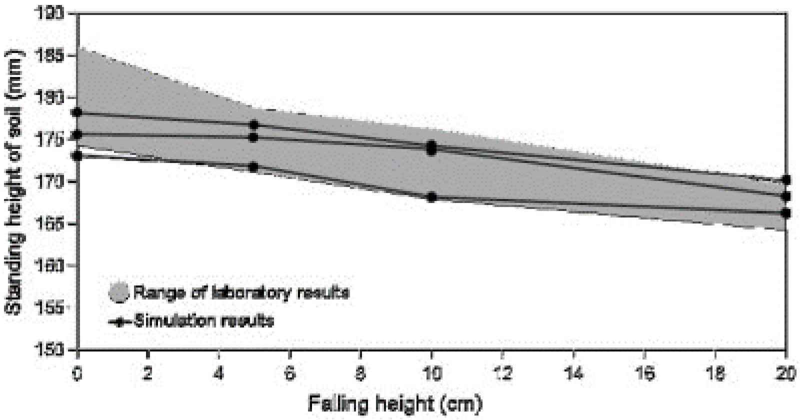


Figure 2.13 Laboratory and simulation results of pluviation tests.

(Vittorio Chiessi et al., 2010) Trajectory graph analysis is significantly affected by parameters, especially the reference recovery value coefficients. To solve problem, calibration model is established on rare field explanations. Geostatistical approaches are suitable because they greatest estimate point source phenomena, as falling rocks. Rockfall hazard analysis; evaluating the possibility of promulgation of potentially unbalanced rocks is critical to hazard research. An engineering geological model of rock rupture and propagation along the slope was subsequently established, and two distinct approaches were taken. Compare the results to check their reliability.

- Deterministic method Rockfall technical analysis; In the proposed case study, the simulation relies on the rockfall path software program, enabling us to determine the arrival point of the rock mass, its trajectory height and flight length characteristics, and the distribution and correlation of its effects. Kinetic energy. ROTOMAP® is a salable package which utilized as a typical model. The kinematic model used treats boulder as a point element rather than an ellipsoid element.

$$V = C_s \sqrt{2gh}$$

Where h is the variation in elevation between the point of detachment and the arrival area, g is the gravity acceleration, and Cs is the damping coefficient that takes account of the sliding, rolling and shocks of blocks.

- Probabilistic Probabilistic method geostatistical methods; this method consider on geostatistical systems might be a substitute or complement to deterministic methods. Among the various geostatistical methods with very interesting applications, the Kriging method and its variants are mentioned. Geostatistical techniques can produce value estimates and variances compared to traditional interpolation techniques.

$$Z_0 = \sum_{i=1}^{n} w_i z_i$$

Where Z0 is the predicted value, wi is a value of i-th mass solution of a system calculated from a set of (n+1) linear equations (where n is the number of points used for estimating a value at the centre of a grid) and zi is the value of the function at the i-th point.

(Murat Gul et al., 2016) Climatic conditions, seismic activity, gravity, differences in matrix strength, and conglomerate particles increase weathering, form blocks, and cause rock fall. In addition to these natural effects, human activities began about 4,000 years ago, and the weathering surface was promoted by carvings, terraces, and rock carvings. RocFall software is used to assess probable rock fall hazards. The friction angle is one of the values obligatory by the program and is calculated to be 37 ± 3 depend on the RocLab presentation. The cleaning of hard rock is caused according to the measuring of surface. For similar applications, the surface roughness is taken as 2. In the program help section, based on some estimation methods of the Rn and Rt recovery coefficient values abridge in previous studies or can be determined by laboratory application and back analysis, continuous formulas of Rn values for different rocks have been proposed. N1 and N2 are Schmidt Hammer rebound number for laboratory work and slab samples. We get them from the typical of the grain and the matrix. It follows that the Rn value and the Rt value are found out from the back analysis of the A section slope 45^0. Using the rock fall parameters as in Table 2.1.

$$R_n = -0.110 + 0.00919 * N_1 + 0.00392 * N_2 + 0.00358 * A$$

Table 2.1 Rack Fall application parameters.

Coefficients	Values
Rn	0.7 ± 0.05
Rt	0.85 ± 0.05
Throw	1000
Friction angle	37° ± 3°
Surface roughness	2
Surface of slope	Clean hard rock

(Mehran Koleini and Jan Louis Van Rooy, 2011) Many factors can cause rocks and weathering to drop off the slope, cracks of counting, cracks, and vibrations of filed, and other external forces. The Rockfall Risk Index FRHI was improved depend on the experimental work of the Oregon and Washington Transportation Bureau. The objective of it is performing stability analysis and structure mapping before employing FRHI. RocFall version 4 was utilized at the Marun Dam site to select source zone where rock fall may occur. The consequence of right flank are shown in Figure 2.14 which three possible source areas have been recognized: overhead 280 meters up to sea level, between 160 and 280 meters up to sea level and below 160 meters from Elevation. As pair of a 10 kg block near the vertical plane, the measurement right bank translation speed, bounce height and kinetic energy are shown in Figures 2.15a, b and c. As appear in these figures, due to the incidence a few of benches on the right face, which presences significant variances in the values resulted for the two faces.

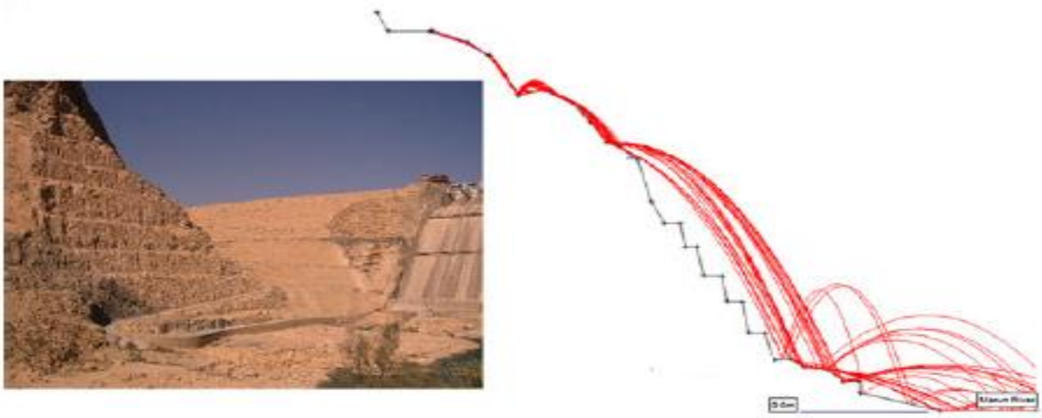


Figure 2.14 Inclination topographic and rockfall path.

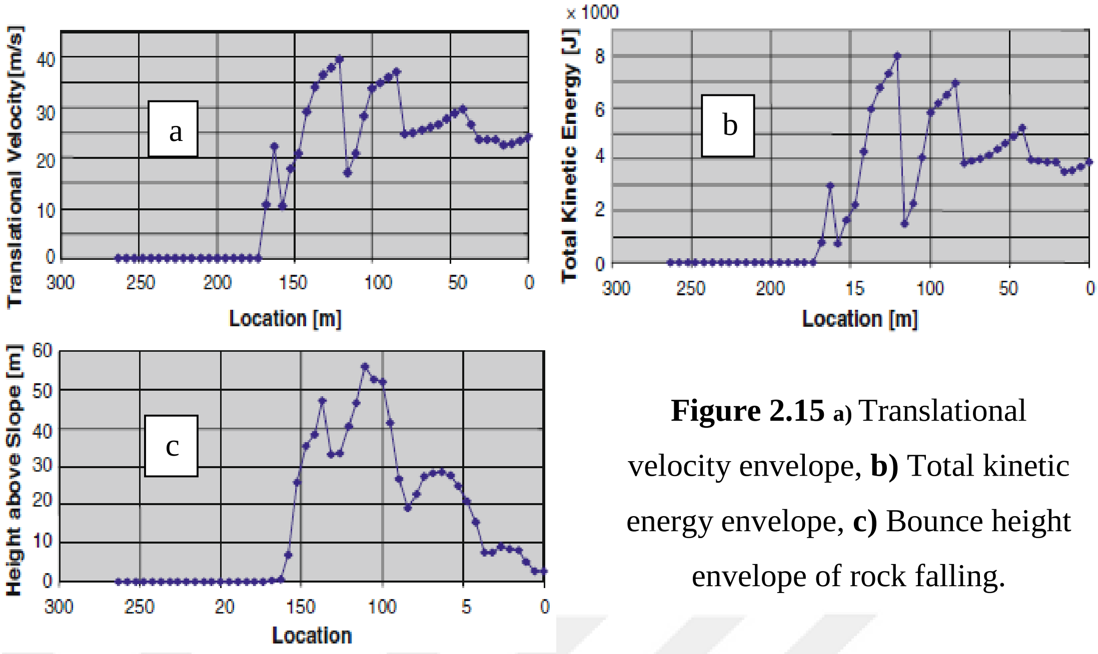


Figure 2.15 **a)** Translational velocity envelope, **b)** Total kinetic energy envelope, **c)** Bounce height envelope of rock falling.

A number of limitations were also evaluated according to study of bounce height, travel distance, kinetic energy, and translational speed. A results of the rockfall analysis presented that the energy and speed caused by the falling of blocks are quite high level sufficient to cause serious crumb. Regarding speed with energy, the realized height of bounce is not very significant. The problem has been exacerbated by the exclusion of trees from inclination without capturing the falling blocks, so most of the rocks cover a very significant distance to lead the valleys that cross the road, imperiling travelers and infrastructure (P. K. Singh et al., 2016).

In a representative rockfall study, the size of the falling block, the falling trajectory, the energy debauchery at dissimilar influence ideas alongside the slope, Also the speed associated through it are actual essential assessments. Because of this reason, the coefficient of restitution (CR) is actual essential parameter. Moreover, this study presented that determined by the back analysis of a number of displaced rock masses detected in the site. At any different tangential recovery (Rt) value, a consistent normal recovery value (Rn) is achieved relative for the falling of block detected in the site and schemed on the graph diagram. The typical is then taken as the best representation of the CR value, which is used for rockfall analysis Figure 2.16 (Lambert C et al., 2012).

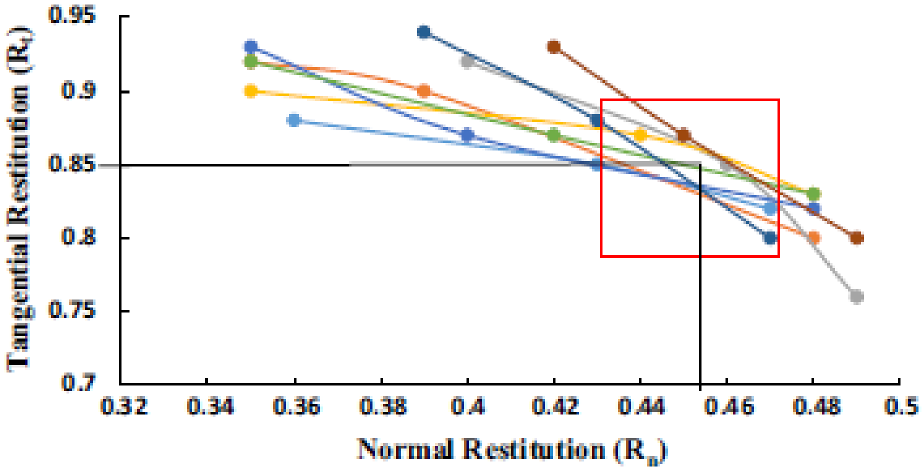


Figure 2.16 Back-analysis method used to determine the values of coefficient of restitution of gneissic rock mass.

Mathematical models are compiled for use by computers. Called CADMA, it allows prediction of the fall trajectory and associated parameters energy, bounce height, and distance for the falling block for remediation work design. The design is depended on rigid body techniques and statistically analyzes the decline in 2-D space. The features and potential of the program are assessed by matching the results of the in-situ test: in overall suitcases, the database typically provides correct calculations of descent speed, energy, height of bounce, and stopping distance (Azzoni et al., 1995).

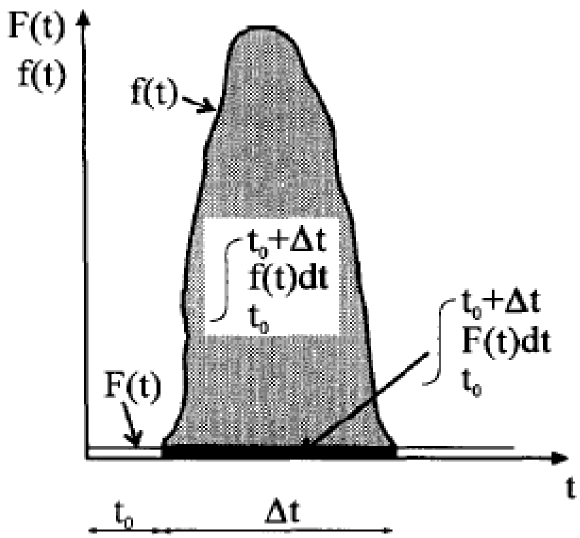


Figure 2.17 Relation between impelling (f) and active F(r) forces in the time interval corresponding to the impact.

$$\int_{t_o}^{t_o+\Delta_t} F(t)dt$$

Represents the impulse of the active forces Figure 2.17

$$\int_{t_o}^{t_o+\Delta_t} f(t)dt$$

Represents the impulse of contact reactive forces.

$$K = k_0 . \in_{max}^{e} = \frac{1}{2} w^2 (I + r^2)$$

$$w = \sqrt{\frac{2 \in_{max}^{e} k_o}{(I + r^2)}}$$

K = Kinematic Energy (KJ).

I= Moment of inertia.

r= Displacement resultant ($r^2=d^2x+d^2y$).

w= angular velocities after the impact. And

$\in_{max}^{e}=$ Restitution coefficient of energy.

In recent years, the instability of rock slopes has become more prevalent during the influence of human events such as path cutting, excavation to build housing areas, construction of large infrastructure and quarries. Empirical design methods do not use formal design methods and calculations, or analytical equations, but rely on the experience and judgment of engineers. Traditionally, design methods and data analysis may vary from engineer to engineer (Ahmed M. Youssef et al., 2015).

(Markus Stoffel et al., 2006) RockyFor is a process-based rockfall simulation model initially improving from survey of site statistics since the Austrian Alps (Dorren et al., 2004). The design has been utilized for 218 real rock trials on forest and non-forest slopes in the French Alps and has been improved and validated. RockyFor uses a raster map as an input file and simulates the trajectory of drops, bounces, and rolling rocks, <0.5 meters in diameter, and megaliths in a single grid unit Ø > 0.5 meters. In addition, it obviously analyzed the influence of rock's falling on specific trees and eventually cumulative each grid cell. The structure model involves of three main units. The first module analyses the rockfall path depended on the terrain of the site, which is characterized by Digital Elevation Model DEM. The second major module estimates the loss of energy during the impact on a single tree.

$$\Delta E = -0.046 + \frac{0.98 + 0.046}{1 + 10^{[0.58-((p_i - CTA)/0.5\, DBH)-8.007]}}$$

Where DE is the largest value of energy in percentage, which can be intemperate by the tree % Pi _ CTA.

Third main module estimates of falling rock velocity after a rebound on the slope surface for details see. At this time, the reduction of velocity after a rebound is mainly based on the lateral coefficient of restitution (rt), which is calculated by the conformation and volume of the particle material layer the surface as well as the radius of the falling rock itself. The value number is measured as a function of the rock radius and the material mean radius on the ground as follows:

$$r_t = \frac{1}{1 + (D_{mean}/D_{rock})}$$

Where D mean is the mean diameter of the material on the slope surface (m) and Drock, the diameter of the falling rock (m). The calculated rt is uniform randomly varied with10%in order to take account: (i) the enormous local variation in the size of material covering rockfall slopes, as well as (ii) the geometry of the falling rock. Furthermore, its value is limited to the range 0.1, 0.99 as to avoid unrealistic energy loss. Instead, we were not capable to verify a delicate expression of the current average impact height. The present version of RockyFor also offer a valuable research tool for studying the protection provided by different stand structures due to its ability to accurately predict the spatial envelope of the rockfall path.

The retarding capability of the superficial material is accurately characterized by a term called a recovery coefficient. The coefficient of this value based on the nature of the material forming the influence surface. The clean plane of the hard rock has a high recovery coefficient, while the soil, gravel and fully decomposed rock have a lower recovery coefficient. So that gravel layers are located on hook benches in order to isolate more bouncing of falling of rocks (Rocscience, 2004). Ratio of outgoing and incoming velocity is presented as a restitution for a material.

$$R = V_{outgoing}/V_{incoming}$$

A fully elastic material will have a recovery factor of one. Matters conspicuous the material will bounce at the similar speed. A totally inelastic material will have a recovery factor of zero. This means that a purpose hitting this material will bounce at zero speed, ie it will stop. The recovery factor for all real materials is between zero and one (Rocscience, 2004).

The tangential recovery coefficient (Rt) and the normal recovery coefficient (Rn) are the two improved the parameter value of the material. The tangential coefficient explains the ratio of the output speed tangential to the surface to the input speed tangential to the surface. The normal factor represented the ratio of the output speed normal to surface to the input speed perpendicular to the surface. The improved tangential coefficient is usually equal to or greater than the normal recovery factor. In addition, back calculation is utilized to calculate the coefficient value of restitution for known rock ways and rock endpoints. In case you have an understanding of past rockfall issues understand the starting point, end point and rock path, so it's possible to utilize them to help calibrate the model design. When you have the letter of "known" rock paths and end points, you have able to choose a coefficient from table of recovery factor, which is choose the value that best describes your site - so you have a good starting point, after that the recovery factor is possible to change. The model design scale the rock path in the ideal is parallel to the perceived rock path (Rocscience, 2004). As over-all instruction, a rigid material will cover a higher coefficient of recovery factor for a softer material, while, in case the normal recovery factor developed, then the value of recovered tangential will growth too.

The value of video analysis in physics education is well established (Beichner 1996, Laws 1998) and both commercial and free educational video analysis programs are readily available. Tracker video (TV) application allow the students to construct simulations of particle model depend on Newton's laws and directly compare their properties to factual substances captured on the videoTracker model generator, certainly reporting and modifying force considerations, factors coefficients, and simply introducing Dynamic modeling, the initial state when hiding the details of a mathematical algorithm. Interactive computer modeling has also proven to be an effective learning tool (Christian 2007, Jackson 2008. This approach actively engages students in the design, implementation and analysis of mathematical models of physical phenomena. With simulation tools such as Easy Java Simulations (EJS 2011, Esquembre 2004), Students can easily change model parameters and expressions, visualize model behavior, and communicate results with others. The design and analysis of computer simulations is similar to laboratory experiments in many ways, and often leads students to discover new insights into system behavior. Computer modeling can be combined with video analytics in a variety of ways. For example, model-generated data can be compared with video data graphically (Heck 2007, Heck 2010) or by driving side-by-side animations (Kedzierska 2009).

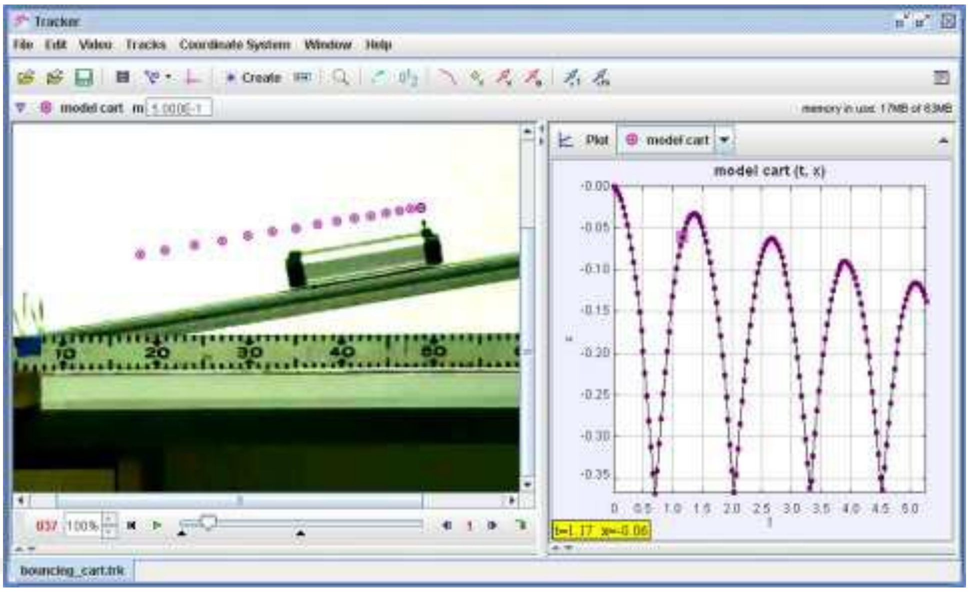


Figure 2.18 Physics tracker software overview

Both of these examples involve gathering video data and then comparing the model with that data. The tracker takes a different approach: the model simulation is drawn directly on the video. Figure 2.18 shows an overview of the physical tracker software. Same time base and coordinate system are able to share because of this simulation and video. Direct visual inspection tend to offer to the applicant to experiment with their model, a procedure that is both instinctive and perceptive. Honestly, the video makes the model active, while the model provides a specific object for the video to compare. Other views of model generation data pictures and tables are accessible too for simulation, and tabbed page views enable authors to include HTML documents, information or movements. The tracker defines two basic types of particle models: 1 analysis and 2 dynamics. In turn, the dynamic particle model can be a Cartesian, polar or two-body system that experiences internal and external forces.

A computational or computer model, and computer simulation, is a software application or network that efforts to analyze a concept of a particular system. Simulation has now been productively applied in several applicant, such as climate estimating, traffic engineering, moreover, and its applicant in training pilots with flight simulators. Enhancing of Trajec3D, this is a three-dimensional hardened rock fall simulation application that simulates shape of a volume, which is the shape due to free fall, bounce, sliding and rolling. It is a modeling instrument that allows you to quickly evaluate a scene to superior realize the possible paths that rocks can track, it will takes a time to reach a section of concentration, and the energy guesses deposited alongside the paths. Trajec3D is improved by using the graphics game, engine and physics engine utilized in asocial program (Basson, F. R. P., 2012).

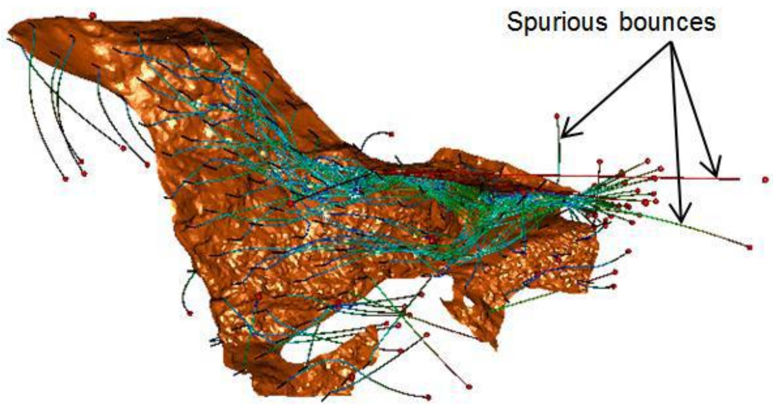


Figure 2.19 Plan and side view of spurious bounces

The physics engine apply as a deterministic solver which create it apposite to real-time physics simulation. Figure 2.19 represented as template everyplace shapes of spherical are unconfined from an unchangeable elevation level onto more comprehensive topography with small triangulations in relation to the fall bodies. Maximum falling substances behave normally with false rebounds are very noticeable. The falling object stays at the boundary of the defined physical volume.

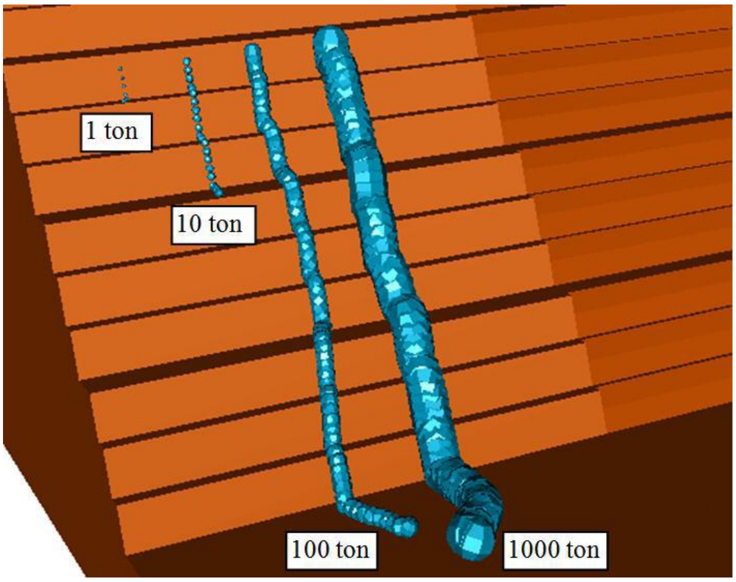


Figure 2.20 Fall bodies with different dimensions.

Figure 2.20 shows the modeled trajectory paths of fall bodies with different masses, and thus different volumes. As expected, the larger blocks are not as easily caught by the berms as the smaller blocks. The larger blocks thus tend to fall further, and are less affected by the catch benches, resulting in greater maximum velocities than the smaller blocks as indicated in Table 2.2.

Table 2.2 Maximum velocity of different fall body masses

Mass (tons)	Maximum velocity (m/s)
1	9.1
10	12.8
100	15.4
1000	16.1

Figure 2.21 shows the modeled trajectories of blocks with the same mass but different shapes. The red fall body to the left is mathematically a perfect sphere, and the other shapes are all angular. The rounded shapes falls furthest down the slope followed by the square shape. Flat fall bodies are usually the most easily caught benches to arrest because they tend to slip and are not easy to roll. The input parameters of rigid body mechanics are few, measurable and intuitive. In addition to shape, mass, and speed, Trajec3D only needs to touch the static and dynamic friction angles and elasticity of

the surface. Elasticity or "elasticity" is defined by the coefficient of restitution, which is a fractional value representing the ratio of the speed before and before the impact, along the impact line. (Basson, F. R. P., 2012).

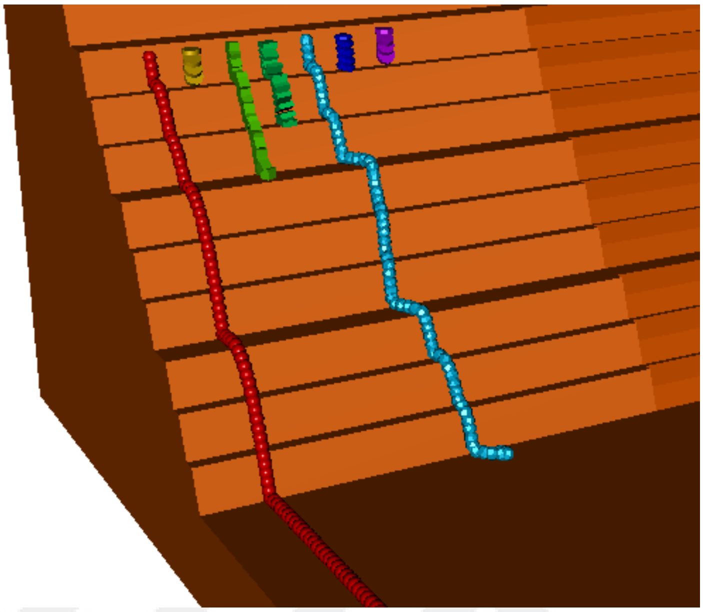


Figure 2.21 Fall bodies with different shapes.

CHAPTER III
METHODOLOGY

3.1. Materials Used and Study Limitation

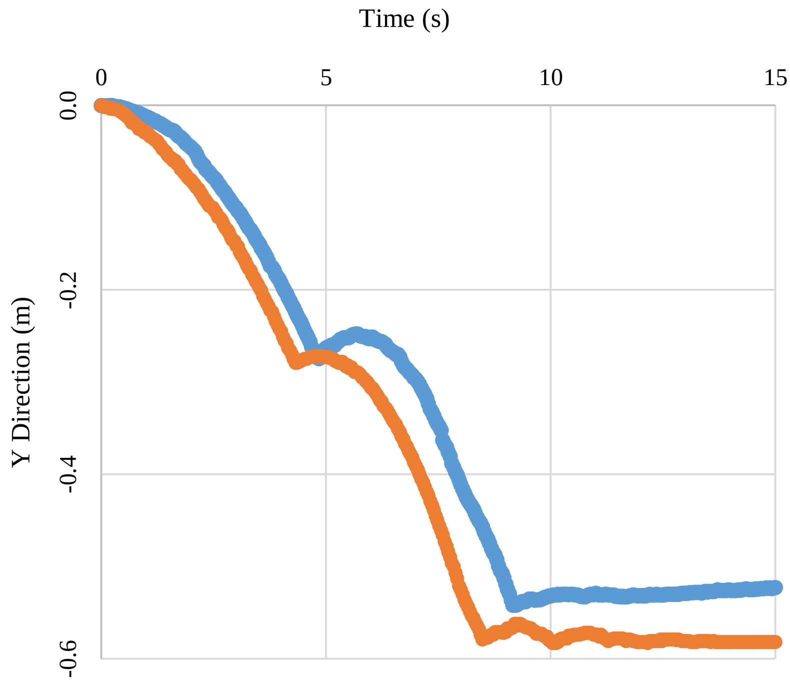
The study includes an observation between laboratory test and computer animation software represented by BLENDER Software. For this purpose two types of materials were selected Wood and Steel in cubic and spherical shapes representing the rock falling with dimensions of 2.7*2.7*2.7cm and diameter of 2.7cm to be falls on a side slope 45 degree made of wood has one stage of 20cm width with slope of 1% at the mid portion. The height of start point of the model is 100cm which it is representing Y direction, the horizontal distance is 130cm at the end point of the model that represent the X direction and the model width is 50cm. Table 3.1 shows the physic properties of samples.

Table 3.1 Materials physic properties.

Name		Dimensions (cm)			Mass (g)	Coefficient of Friction	Bounciness
		x	y	z			
Cubic	Steel	2.7	2.7	2.7	148.90	0.31	0.03
	Wood	2.7	2.7	2.7	10.04	0.33	0.04
Spherical	Steel	2.7	2.7	2.7	80.20	0.21	0.35
	Wood	2.7	2.7	2.7	7.09	0.25	0.40

Low values are used for the initial velocity starting with zero m/s in case only freeze–thaw, rain, snow and wind are effective for the rock fall, Behavior of patterns influences by Surface roughness of falling materials (Barton and Choubey 1977; Kemthong 2006; Liao et al. 2008) but in Laboratory tests the effects are neglected due to room conditions, and the surface roughness not considered in the calculations due to the slope and the sample model that used as same for all cases. Figure 3.1 shows the model and sample falling alignment.

(a)

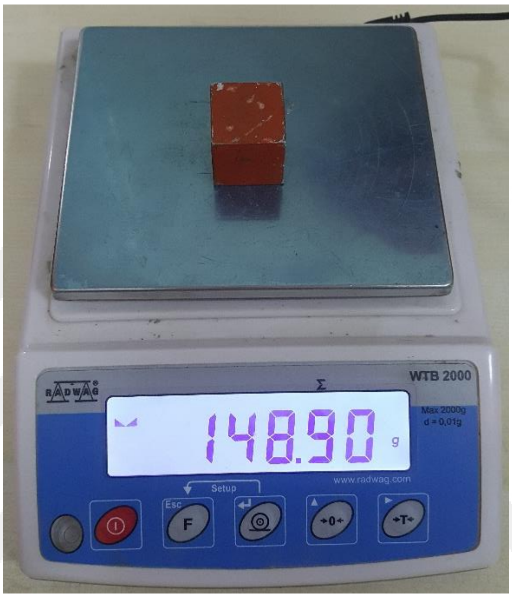


(b)

Figure 3.1 (a) Study laboratory model **(b)** Sample alignment falling in Y-direction.

3.1.1. Steel Material

Cubic steel material made from pure steel was used for this study with a bounciness of 0.03 and coefficient of friction as 0.31 (Mark Mounts, 2007; Engineering ToolBox, 2004). From the same properties and references spherical steel material used with a bounciness of 0.35 and coefficient of friction as 0.21. Figure 3.2a and b represents the steel material samples by their weights.



(a)

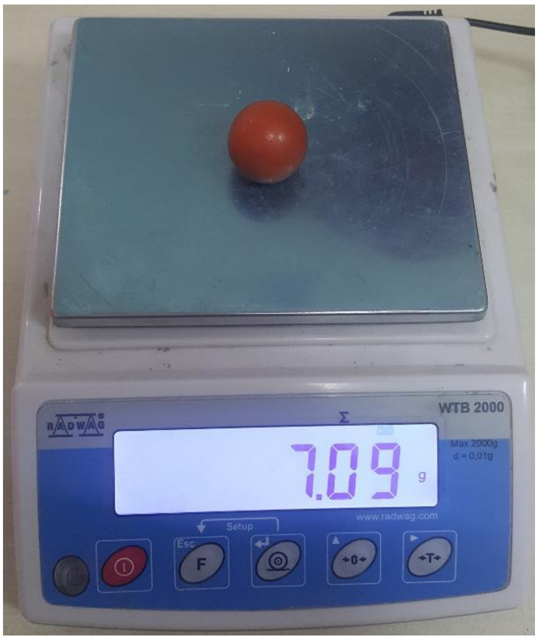
(b)

Figure 3.2 shows the (a) cubic and (b) spherical steel models with their weights.

3.1.2. Wood Material

Cubic, spherical and side slope stand materials made from timber wood the cubic wood sample used with a bounciness of 0.04 and coefficient of friction as 0.33 (Mark Mounts, 2007; Engineering ToolBox, 2004). From the same references spherical wood sample used with a bounciness of 0.40 and coefficient of friction as 0.25. Figure 3.3a and b represents the wood material samples by their weights.

(a)



(b)

Figure 3.3 shows the (a) cubic and (b) spherical wood models with their weights

3.2. BLENDER Software Model

Previously many type of animations software used by researchers to simulate the engineering problems, in the last years BLENDER Software is the most popular software used through the international animation films that increases the quality of the films due to its flexibility of being an open source and free of charges. In this study BLENDER Software was used for simulate the motion of the falling Cubic and spherical materials, the version which used in this study it is BLENDER 2.78c justifies on 25 frame/sec. for rendered videos. Figure 3.4 shows the frame representing BLENDER software process, and Figure 3.5 shows the BLENDER software camera view.

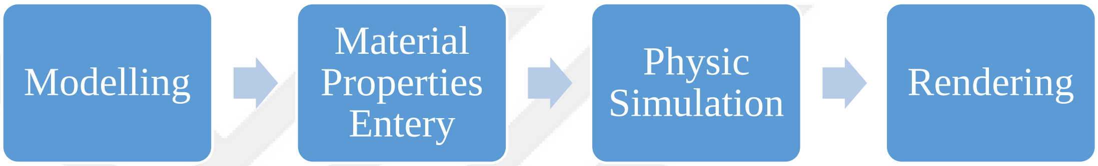


Figure 3.4 Frame representing BLENDER software process

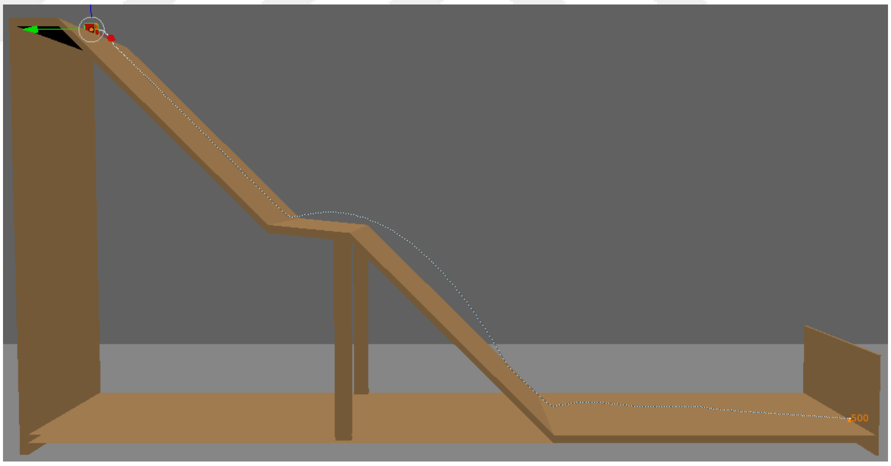


Figure 3.5 Shows the BLENDER software camera view.

3.3. Laboratory Video Record Camera

The laboratory tests documented through video camera justified on 25 frame/sec. and has a minimum 12-megapixel to record the film and motion of the objects clearly that can be tracked easily, video record used for comparing purposes with the motions of computer software model that prepared to represent the rockfall trajectory. Figure 3.6 shows the camera view captured by video camera.

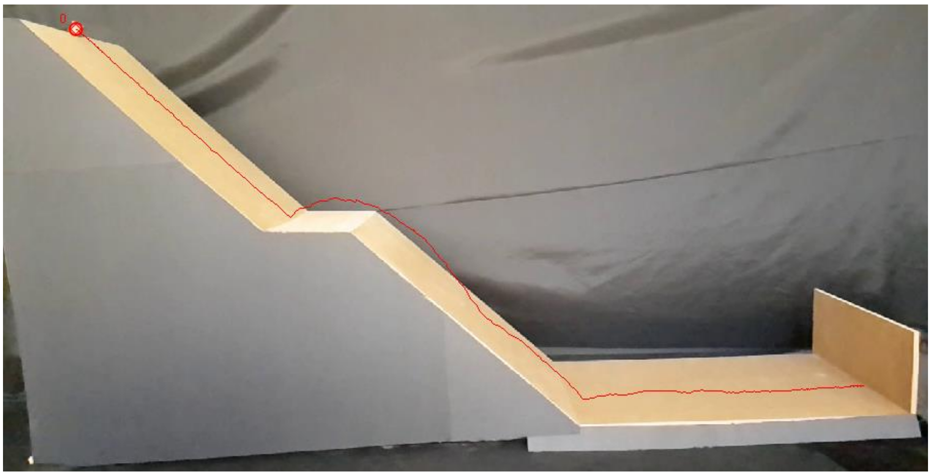


Figure 3.6 Shows the laboratory camera view.

3.4. Physic Tracker

Tracker is a free video analysis and modeling tool built on the Open Source Physics (OSP) Java framework. It is designed to be used in physics education (Douglas Brown, Wolfgang Christian 2011). The Tracker video analysis and modeling program enables students to create particle model simulations based on Newton's laws and to compare their behavior directly with that of real-world objects captured on video by tracking selected objects movement, the version which used in this study it is (TRACKER 5.0.7). Figure 3.7 shows the frame representing BLENDER software process.

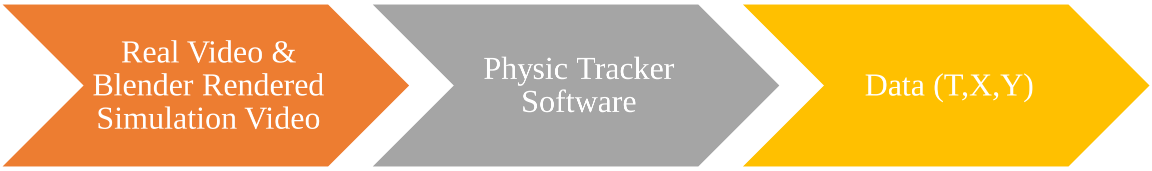


Figure 3.7 shows the frame representing BLENDER software process.

3.5. Statistical Tests

Statistical tests performed to find the degree of R, R square, significance rate P-value, Standard Deviation, degree of freedom, correlation by using the T-Test and regression analyzes in statistical software SPSS to compare the reality between the actual representing laboratory and the Blender software simulation, the version which used in this study it is IBM SPSS Statistics 23.

CHAPTER IV
RESULTS AND DISCUSSIONS

4.1. Wood and Steel Cubic Shapes

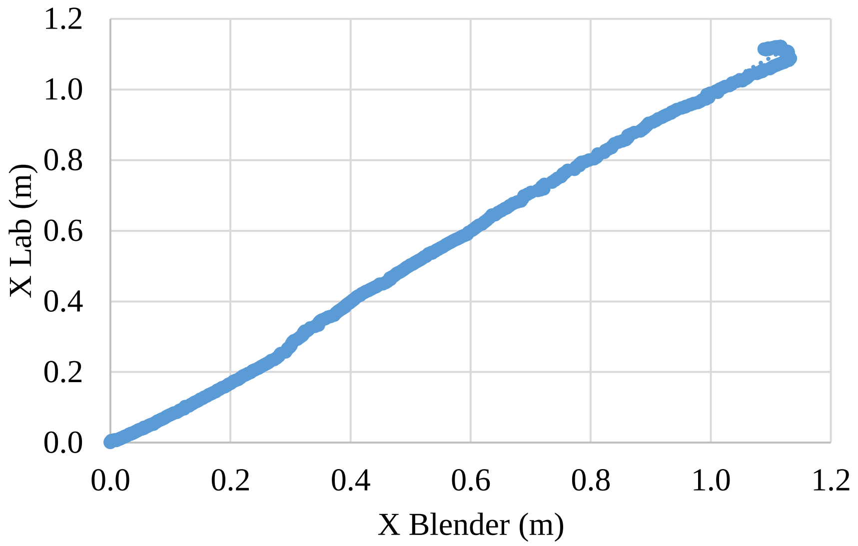
4.1.1. T-Test and P-Value

Trials conducted in laboratory to simulate the rock falling on the road side slopes by using the typical model prepared in this study, the data for the best trial is analyzed and tested for Cubic shape samples with different parameters according to the study methodology. Table 4.1 shows the results between these parameters.

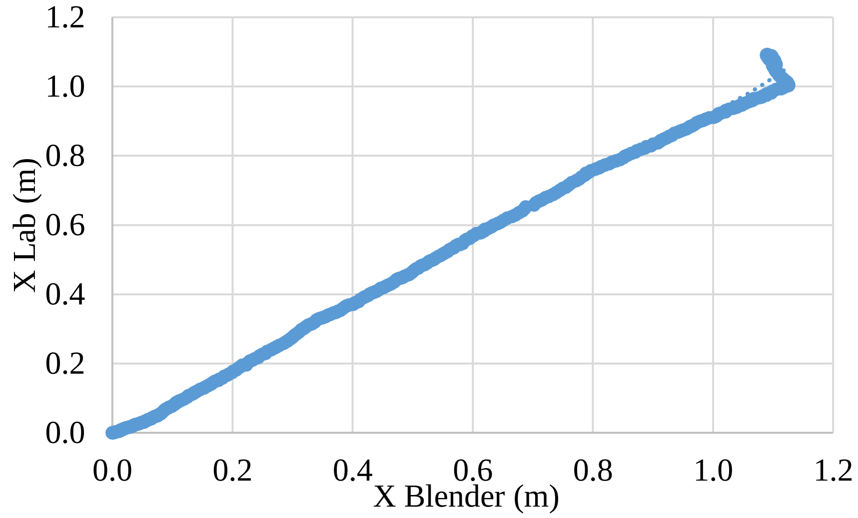
Table 4.1 Statistical results of cubic samples from SPSS analysis.

Material Name	Tested Parameters	No. of Data	Correlation	R	R Square	S. D.	Significant	Degree of Freedom
Wood	X lab - X blender	380	0.999	0.999	0.998	0.015	0.000	379
	Y lab - Y blender	380	0.997	0.997	0.994	0.013	0.000	379
	V lab - V blender	380	0.999	0.999	0.998	0.17	0.000	379
Steel	X lab - X blender	346	0.999	0.999	0.997	0.019	0.000	345
	Y lab - Y blender	346	0.982	0.982	0.965	0.036	0.000	345
	V lab - V blender	346	0.998	0.998	0.996	0.237	0.000	345

The data from laboratories and BLENDER in Table 4.1 seems have high relations and a best correlation. When a testing done between the X Horizontal Distance data related laboratories and BLENDER for wood sample, the output shows that the R^2 between them is 0.998, R is 0.999 and a very low standard deviation amount of 0.015, Figure 4.1a Approximately the same relation happened between the Y Vertical Distance data for both ways, R^2=0.994, R=0.997 and SD. =0.013. Figure 4.2a while the same relations appeared for steel sample but in lower correlation by about 0.1% in R^2, almost corresponded in R and 0.3% in SD. for X direction and 2.9% in R^2, 1.5% in R and 2.3% in SD. for Y direction.

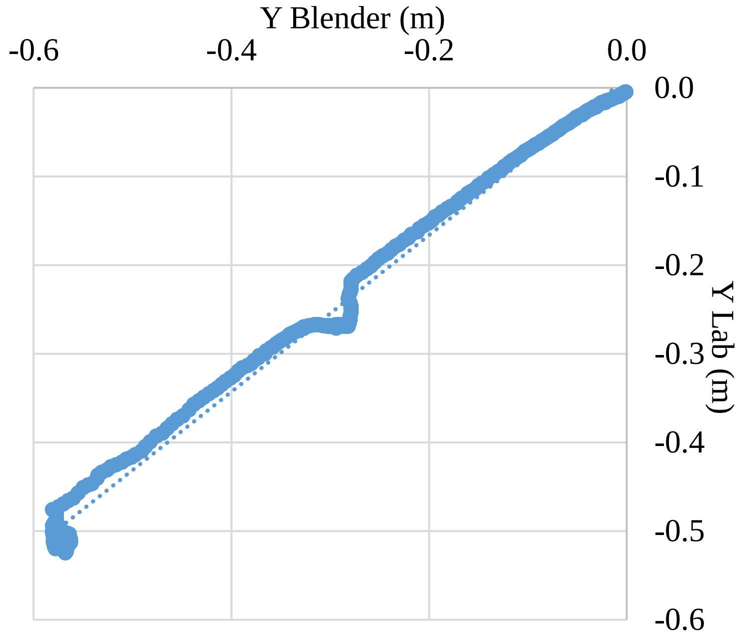


(a)

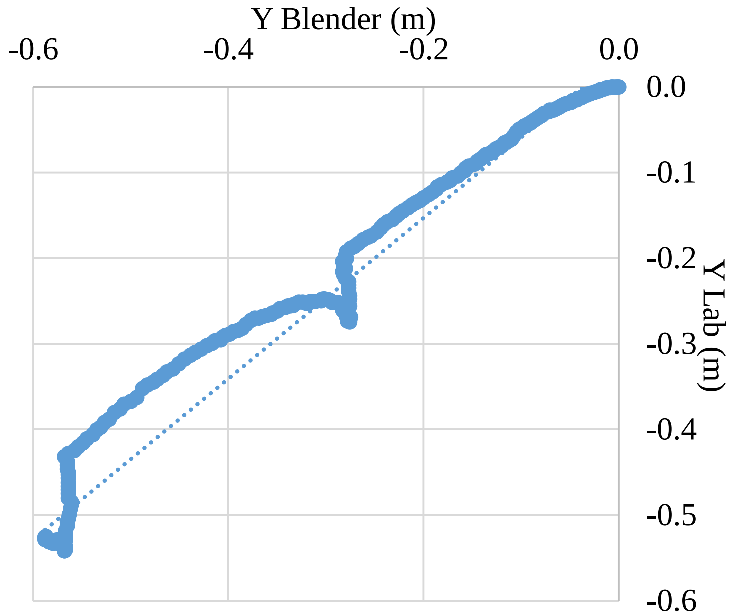


(b)

Figure 4.1 Relation between X Lab and X Blender (a) wood (b) steel cubic samples.



(a)



(b)

Figure 4.2 Relation between Y Lab and Y Blender (a) wood (b) steel cubic samples.

By doing regression analysis between the X, Y and T for laboratory equations 1 and 3 and BLENDER equations 2 and 4 are obtained for finding the velocities as follow;

For cubic wood sample,

$v_{lab} = 1.154 + 10.861x + 1.165y$ Eq. (1)

$v_{BLENDAR} = 0.871 + 10.248x + 2.421y$ Eq. (2)

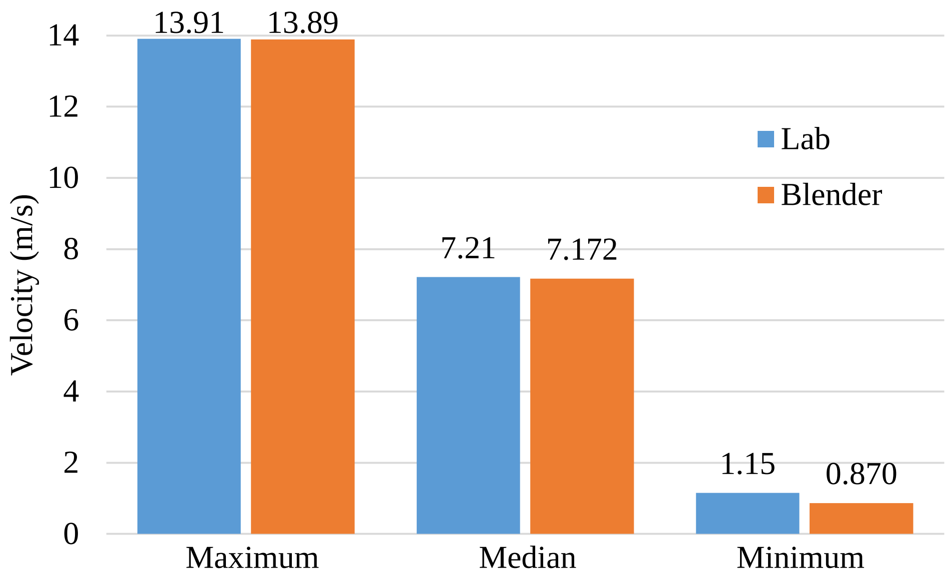
For cubic steel sample,

$v_{lab} = 1.262 + 10.830x + 0.243y$ Eq. (3)

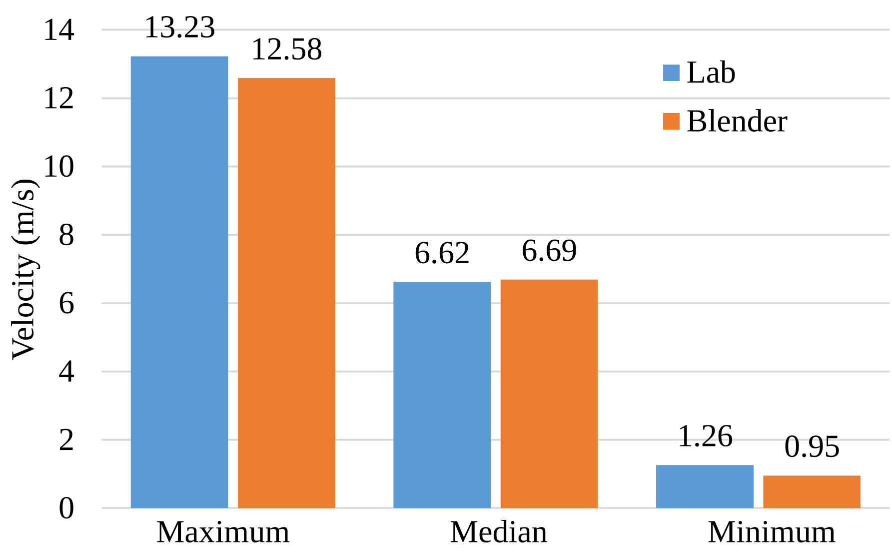
$v_{BLENDAR} = 0.953 + 9.006x + 2.557y$ Eq. (4)

4.1.2. Velocity

Testing for the V values of wood and steel cubic shape for both laboratory and BLENDER done to compare and finding the degrees of relation between them Table 4.1, For wood sample founded that R^2 is 0.998, R is 0.999 and SD. is 0.017 between the laboratory and BLENDER data, however; these rates insuring the ability of BLENDER software to simulating the reality of rock falling on side slopes. There are no different in test results for steel sample, the same relations occurred as in steel sample but in few lower rates. Figures 4.3a and b although there is a little bit neglect able difference in maximum velocity for wood and median velocity for steel samples with that ones in BLENDER, that's due to errors from laboratory environment and sample preparations.



(a)



(b)

Figure 4.3 Relation between V Lab and V Blender (a) wood (b) steel cubic samples.

The P-Value the significance for whole data Table 4.1 is 0.00 < 0.05 explaining that all data depended in this study is confidence and can be taken in consideration for real applications.

4.2. Wood and Steel Spherical Shapes

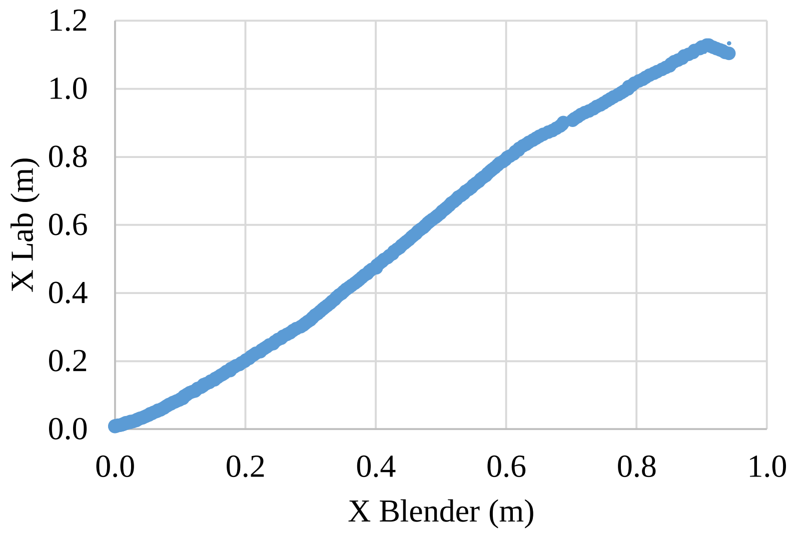
4.2.1. T-Test and P-Value

Trials conducted in laboratory to simulate the rock falling on the road side slopes by using the typical model prepared in this study, the data for the best trial is analyzed and tested for spherical shape samples with different parameters according to the study methodology. Table 4.2 shows the results between these parameters.

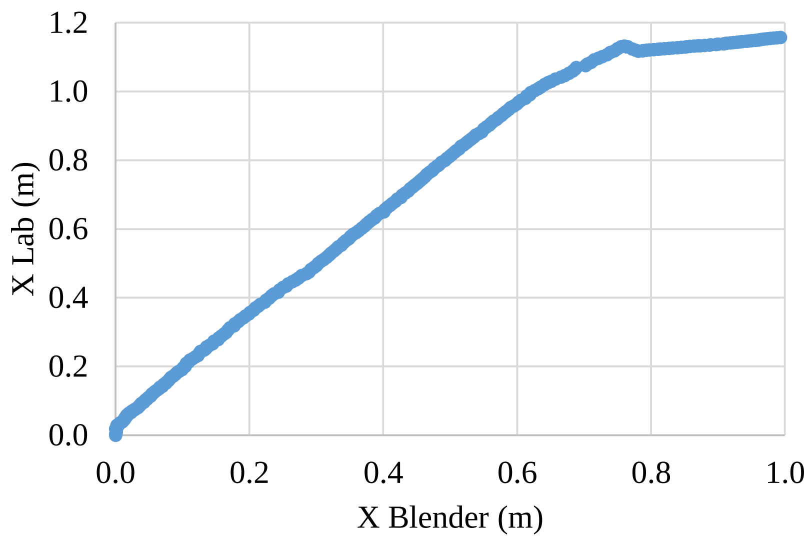
Table 4.2 Statistical results of spherical samples from SPSS analysis.

Material Name	Tested Parameters	No. of Data	Correlation	R	R Square	S. D.	Significant	Degree of Freedom
Wood	X lab - X blender	260	0.997	0.997	0.995	0.026	0.000	259
	Y lab - Y blender	260	0.966	0.966	0.932	0.044	0.000	259
	V lab - V blender	260	0.995	0.995	0.989	0.31	0.000	259
Steel	X lab - X blender	275	0.981	0.981	0.963	0.077	0.000	274
	Y lab - Y blender	275	0.946	0.946	0.895	0.057	0.000	274
	V lab - V blender	275	0.968	0.968	0.937	0.91	0.000	274

The data from laboratories and BLENDER in Table 4.2 seems have high relations and a best correlation. When a testing done between the X Horizontal Distance data related laboratories and BLENDER for wood sample, the output shows that the R^2 between them is 0.995, R is 0.997 and a very low standard deviation amount of 0.026, Figure 4.4a Approximately the same relation happened between the Y Vertical Distance data for both ways, R^2=0.932, R=0.996 and SD. =0.044. Figure 4.5a while the same relations appeared for steel sample but in lower correlation by about 3.2% in R^2, for R nearly about 1.6% and 5.1% different in SD. for X direction and 3.7% in R^2, 2% in R and 1.3% in SD. for Y direction.

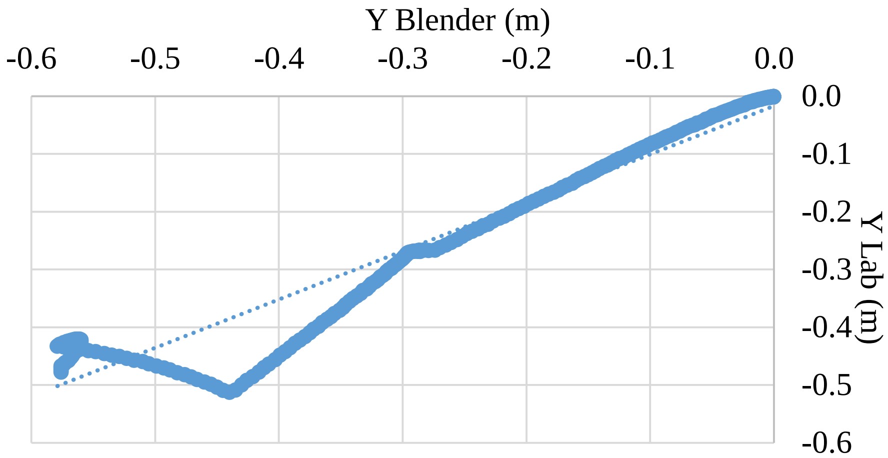


(a)

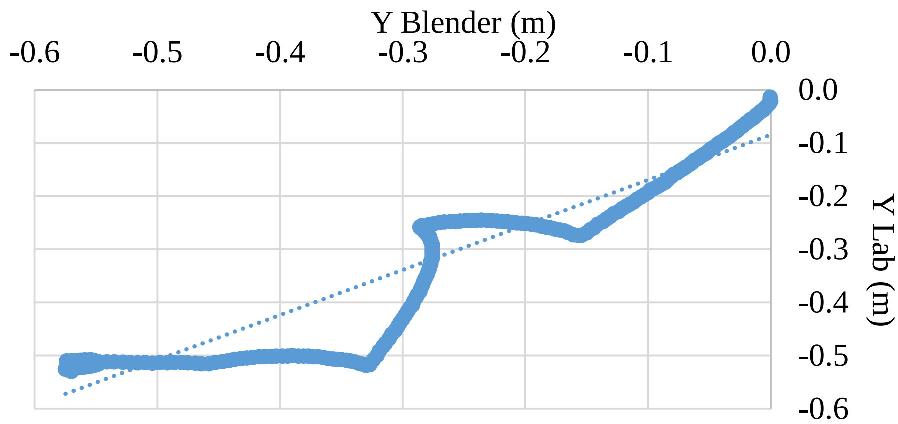


(b)

Figure 4.4 Relation between X Lab and X Blender (a) wood (b) steel sphere samples.



(a)



(b)

Figure 4.5 Relation between Y Lab and Y Blender (a) wood (b) steel sphere samples.

By doing regression analysis between the X, Y and T for laboratory equations 5 and 7 and BLENDER equations 6 and 8 are obtained for finding the velocities as follow;

For spherical wood sample,

$$v_{lab} = 1.146 + 5.708x + 5.296y \qquad \text{Eq. (5)}$$

$$v_{BLENDAR} = 0.981 + 5.979x + 6.691y \qquad \text{Eq. (6)}$$

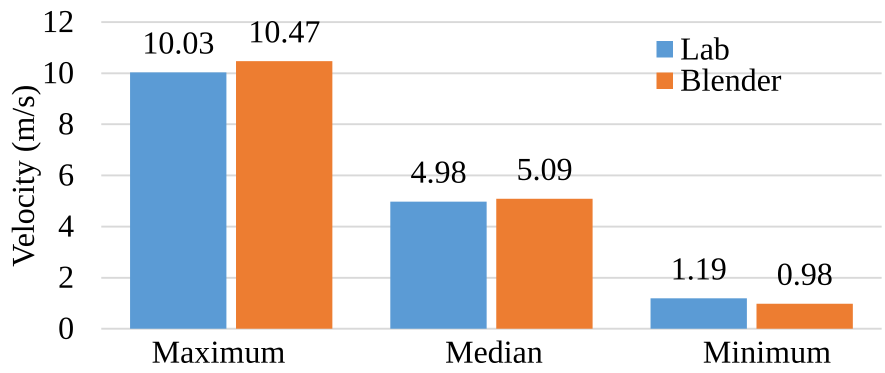
For spherical steel sample,

$$v_{lab} = 0.607 + 8.541x + (-1.403y) \qquad \text{Eq. (7)}$$

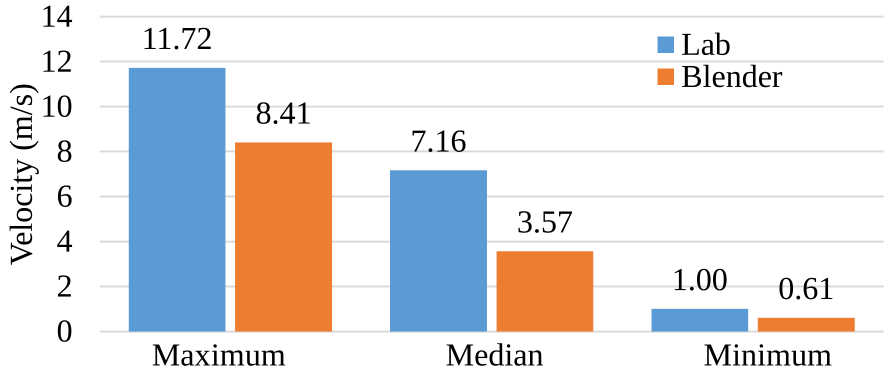
$$v_{BLENDAR} = 1.001 + 6.436x + 6.145y \qquad \text{Eq. (8)}$$

4.2.2. Velocity

Testing for the V values of wood and steel spherical shape for both laboratory and BLENDER done to compare and finding the degrees of relation between them Table 4.2, For wood sample founded that R^2 is 0.989, R is 0.995 and SD. is 0.31 between the laboratory and BLENDER data, however; these rates insuring the ability of BLENDER software to simulating the reality of rock falling on side slopes. There are a slight different in test results for steel sample comparing with wood sample but in few lower rates. Figures 4.6a and b although there is a little bit neglect able difference in maximum velocity for wood and minimum velocity for steel samples with that ones in BLENDER, that's due to errors from laboratory environment and sample preparations.



(a)



(b)

Figure 4.6 Relation between V Lab and V Blender (a) wood (b) steel sphere samples.

The P-Value the significance for whole data Table 4.1 is 0.00 < 0.05 explaining that all data depended in this study is confidence and can be taken in consideration for real applications.

CHAPTER V
CONCLUTION

5.1. Conclusion

The data from both ways procedures analyzed for different parameters to produce the capability of BLENDER Software to be used in simulating the rock fall phenomena in nature happening in side slopes especially in highways, the following notes were obtained:

- BLENDER Software can be used to simulate the rock falling phenomena due to high positive results obtained from the study. While testing process founded that BLENDER Software is too practice software in this direction of simulating works. It covers all major variables and parameters simply.
- This study presented that the statistics result as R^2 of spherical shape in both wood and steel are almost corresponded such an average of 97.2% and 93.2% respectively. Furthermore, the same approach for cubic shape expected that results are approximately similar.
- According to utilizing cubic wood and steel in this study, the results realized that the BLENDER is very appropriate in using different material's mass.
- BLENDER Software and Physic Tracker are open source programs and can be obtained easily free of charges.

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APPENDIX A

Table A.1 Template of Cubic wood data sheet for laboratory and BLENDER software.

Cubic Wood		Lab			Blender		
step	t	x	y	V	x	y	V
0	0.000	0.000	0.000	1.154	0.000	0.000	0.870
1	0.040	0.002	0.001	1.173	0.000	0.000	0.870
2	0.080	0.003	0.002	1.188	0.001	0.000	0.880
3	0.120	0.003	0.003	1.191	0.001	0.000	0.880
4	0.160	0.004	0.004	1.205	0.001	0.000	0.881
5	0.200	0.005	0.005	1.214	0.004	0.001	0.914
6	0.240	0.005	0.004	1.216	0.004	0.002	0.916
7	0.280	0.006	0.005	1.225	0.002	0.002	0.897
8	0.320	0.006	0.006	1.226	0.005	0.002	0.928
9	0.360	0.006	0.006	1.226	0.007	0.003	0.950
10	0.400	0.006	0.006	1.227	0.010	0.004	0.984
11	0.440	0.008	0.007	1.245	0.007	0.004	0.953
12	0.480	0.008	0.007	1.249	0.012	0.005	1.006
13	0.520	0.009	0.008	1.258	0.012	0.006	1.009
14	0.560	0.009	0.009	1.262	0.014	0.007	1.032
15	0.600	0.010	0.009	1.273	0.016	0.007	1.052
16	0.640	0.010	0.010	1.274	0.016	0.008	1.055
17	0.680	0.012	0.010	1.296	0.017	0.010	1.069
18	0.720	0.013	0.011	1.304	0.018	0.012	1.083
19	0.760	0.014	0.011	1.319	0.020	0.013	1.107
20	0.800	0.014	0.012	1.323	0.021	0.014	1.121
21	0.840	0.015	0.013	1.336	0.023	0.016	1.145
22	0.880	0.017	0.014	1.350	0.024	0.017	1.159
23	0.920	0.018	0.014	1.362	0.024	0.020	1.166
24	0.960	0.019	0.015	1.373	0.026	0.022	1.190
25	1.000	0.020	0.016	1.388	0.028	0.022	1.210
26	1.040	0.023	0.017	1.421	0.031	0.025	1.250
27	1.080	0.023	0.018	1.425	0.031	0.027	1.254
28	1.120	0.024	0.018	1.435	0.034	0.028	1.287
29	1.160	0.026	0.019	1.459	0.034	0.029	1.290
30	1.200	0.026	0.022	1.466	0.038	0.031	1.335

Table A.2 Template of Cubic metal data sheet for laboratory and BLENDER software.

Cubic Metal		Lab			Blender		
step	t	x	y	V	x	y	V
0	0.000	0.000	0.000	1.262	0.000	0.000	0.953
1	0.040	0.000	0.000	1.262	0.000	0.001	0.956
2	0.080	0.000	0.000	1.262	0.001	0.002	0.967
3	0.120	0.000	0.000	1.262	0.000	0.003	0.961
4	0.160	0.001	0.000	1.273	0.002	0.004	0.982
5	0.200	0.001	0.000	1.273	0.002	0.007	0.989
6	0.240	0.001	0.000	1.273	0.003	0.007	0.999
7	0.280	0.001	0.001	1.274	0.002	0.009	0.994
8	0.320	0.002	0.001	1.284	0.004	0.011	1.016
9	0.360	0.002	0.002	1.287	0.005	0.013	1.030
10	0.400	0.003	0.002	1.295	0.006	0.012	1.039
11	0.440	0.003	0.002	1.298	0.007	0.015	1.054
12	0.480	0.004	0.003	1.306	0.009	0.016	1.075
13	0.520	0.004	0.003	1.310	0.010	0.018	1.090
14	0.560	0.005	0.004	1.317	0.011	0.019	1.102
15	0.600	0.005	0.005	1.322	0.012	0.020	1.112
16	0.640	0.007	0.005	1.334	0.013	0.022	1.125
17	0.680	0.007	0.006	1.345	0.014	0.024	1.141
18	0.720	0.008	0.007	1.350	0.014	0.025	1.144
19	0.760	0.009	0.007	1.356	0.015	0.028	1.161
20	0.800	0.010	0.008	1.369	0.017	0.029	1.181
21	0.840	0.011	0.009	1.379	0.017	0.032	1.189
22	0.880	0.012	0.010	1.389	0.019	0.033	1.208
23	0.920	0.013	0.011	1.402	0.020	0.035	1.224
24	0.960	0.014	0.012	1.415	0.023	0.037	1.254
25	1.000	0.015	0.012	1.424	0.024	0.038	1.266
26	1.040	0.016	0.013	1.435	0.027	0.039	1.296
27	1.080	0.017	0.014	1.448	0.028	0.042	1.313
28	1.120	0.018	0.015	1.460	0.030	0.043	1.333
29	1.160	0.019	0.016	1.469	0.033	0.047	1.370
30	1.200	0.021	0.017	1.490	0.034	0.048	1.382

Table A.3 Template of sphere metal data sheet for laboratory and BLENDER software.

Sphere Metal		Lab			Blender		
step	t	x	y	V	x	y	V
0	0.000	0.000	0.000	1.002	0.000	0.000	0.607
1	0.040	0.004	0.001	1.033	0.000	0.000	0.607
2	0.080	0.010	0.006	1.100	0.001	0.000	0.616
3	0.120	0.019	0.014	1.210	0.000	0.000	0.606
4	0.160	0.023	0.018	1.263	0.002	0.000	0.624
5	0.200	0.025	0.019	1.280	0.002	0.000	0.624
6	0.240	0.026	0.021	1.298	0.003	0.000	0.633
7	0.280	0.028	0.021	1.313	0.002	0.000	0.624
8	0.320	0.030	0.023	1.334	0.004	0.000	0.641
9	0.360	0.032	0.023	1.350	0.005	0.001	0.649
10	0.400	0.034	0.026	1.384	0.006	0.001	0.656
11	0.440	0.036	0.027	1.400	0.007	0.002	0.664
12	0.480	0.038	0.030	1.428	0.009	0.003	0.680
13	0.520	0.040	0.032	1.453	0.010	0.003	0.688
14	0.560	0.042	0.034	1.476	0.011	0.004	0.695
15	0.600	0.044	0.035	1.501	0.012	0.005	0.703
16	0.640	0.046	0.038	1.529	0.013	0.006	0.710
17	0.680	0.048	0.040	1.554	0.014	0.007	0.717
18	0.720	0.050	0.041	1.578	0.014	0.008	0.715
19	0.760	0.053	0.044	1.612	0.015	0.009	0.722
20	0.800	0.056	0.046	1.642	0.017	0.011	0.737
21	0.840	0.059	0.048	1.672	0.017	0.012	0.736
22	0.880	0.061	0.051	1.706	0.019	0.013	0.751
23	0.920	0.064	0.053	1.738	0.020	0.014	0.758
24	0.960	0.066	0.055	1.761	0.023	0.015	0.782
25	1.000	0.069	0.056	1.795	0.024	0.017	0.789
26	1.040	0.073	0.059	1.833	0.027	0.018	0.812
27	1.080	0.075	0.062	1.862	0.028	0.019	0.819
28	1.120	0.077	0.064	1.887	0.030	0.021	0.834
29	1.160	0.080	0.067	1.927	0.033	0.022	0.858
30	1.200	0.083	0.070	1.962	0.034	0.024	0.864

Table A.4 Template of sphere wood data sheet for laboratory and BLENDER software.

Sphere Metal		Lab			Blender		
step	t	x	y	V	x	y	V
0	0.000	0.008	0.000	1.193	0.000	0.000	0.983
1	0.040	0.008	0.001	1.200	0.000	0.000	0.982
2	0.080	0.009	0.001	1.202	0.001	0.000	0.989
3	0.120	0.010	0.001	1.204	0.000	0.000	0.983
4	0.160	0.010	0.001	1.205	0.002	0.000	0.995
5	0.200	0.010	0.001	1.206	0.002	0.000	0.995
6	0.240	0.010	0.001	1.210	0.003	0.000	1.001
7	0.280	0.010	0.001	1.213	0.002	0.000	0.995
8	0.320	0.011	0.001	1.214	0.004	0.001	1.011
9	0.360	0.011	0.001	1.217	0.005	0.002	1.021
10	0.400	0.011	0.001	1.217	0.006	0.002	1.028
11	0.440	0.012	0.001	1.221	0.007	0.002	1.038
12	0.480	0.012	0.002	1.228	0.009	0.003	1.055
13	0.520	0.013	0.002	1.228	0.010	0.004	1.064
14	0.560	0.013	0.002	1.236	0.011	0.004	1.077
15	0.600	0.014	0.003	1.242	0.012	0.005	1.088
16	0.640	0.015	0.003	1.246	0.013	0.006	1.102
17	0.680	0.015	0.004	1.251	0.014	0.007	1.113
18	0.720	0.016	0.004	1.259	0.014	0.008	1.121
19	0.760	0.016	0.004	1.263	0.015	0.010	1.135
20	0.800	0.017	0.005	1.274	0.017	0.011	1.156
21	0.840	0.019	0.006	1.284	0.017	0.012	1.164
22	0.880	0.019	0.007	1.293	0.019	0.014	1.185
23	0.920	0.020	0.007	1.298	0.020	0.015	1.200
24	0.960	0.020	0.008	1.301	0.023	0.016	1.225
25	1.000	0.023	0.009	1.325	0.024	0.017	1.239
26	1.040	0.023	0.010	1.327	0.027	0.019	1.266
27	1.080	0.023	0.011	1.333	0.028	0.020	1.282
28	1.120	0.025	0.011	1.348	0.030	0.021	1.303
29	1.160	0.026	0.013	1.364	0.033	0.023	1.330
30	1.200	0.028	0.015	1.386	0.034	0.024	1.346

APPENDIX B

Figure B.1 Laboratory model construction

Figure B.2 Laboratory falling sample preparation

Figure B.3 Laboratory video camera justification

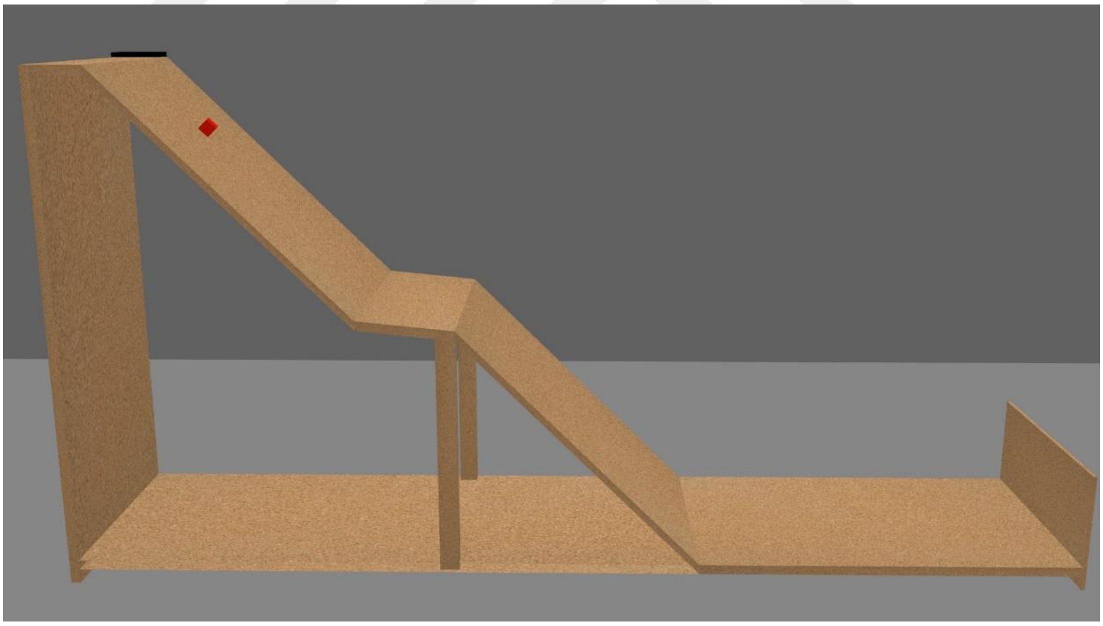

Figure B.4 Blender software model overview

PERSONAL INFORMATION

Name and Surname: Ahmad G. KHOSHNAW

Birth place and date: Iraq-Erbil / 09-February-1993

Phone number: +964 750 456 7210

+90 537 882 6494

Email Address: ahmadganjeena@gmail.com

ahmadganjeena@yahoo.com

Foreign Languages:

Kurdish

Turkish

English

Arabic

Work experience:

Date	Place	Enrolment
2016-2018	World Food Program (WFP)	Civil Engineer
2015-2016	Rönesans Holding	Quality Control Engineer
2014-2015	AK for Engineers	Administration