DESIGN AND FABRICATION OF EQUIPMENT FOR THE MEASUREMENT OF ANGLE OF REPOSE OF GRAINS

BY

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2003/14793EA

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BEING A FINAL YEAR PROJECT SUBMITTED IN PARTIAL FULFUILMENT OF THE REQUIREMENT FOR THE AWARD OF BACHELOR OF ENGINEERING (B.ENG). DEGREE IN AGRICULTURAL AND BIO – RESOURCES. ENGINEERING, FEDERAL UNIVERSITY OF TECHNOLOGY,

MINNA

NOVEMBER, 2008

DECLARATION

I hereby declare that this project is a record of a research work that was undertaken and written by me. It has not been presented before for any degree or diploma or certificate at any university or institution. Information derived from personal communications published and unpublished works of others were dully represented in the text.

DEJI SUNDAY

18/11/08
DATE

CERTIFICATION

This project entitled "Design and fabrication of equipment for the measurement of angle of repose of grain" by DEJI SUNDAY meets the regulation governing the award of the degree of bachelor of engineering (B. ENG) of the federal university of technology Minna, and it is approved for its contribution of scientific knowledge and literacy presentation.

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DEDICATION

This project work is dedicated to God Almighty who have given me the grace nd strength for accomplishment and my parents for their support although this egree program and also to my lovely sisters may God give them long life so that hey can reap the fruit of their labour (Amen).

ACKNOWLEDGEMENT

My sincere gratitude goes to God Almighty for his grace and strength lthough my degree program, may his grace continue seeing me through all through ny endeavor in life (Amen).

ABSTRACT

The work here presents the Design and Fabrication of Equipment for the Measurement of Angle of Repose of Grains. The two method of measuring angle of repose of grain are kramer's method and fowler and watt method were applied. The angle of internal friction is the ratio of force of friction and the force normal to the surface of contact. The effect of physical properties e.g grain shape, size, density and moisture content have effect on angle of repose and angle of internal friction. The materials used for the development of equipments are wood, metal, plastic. The equipment was fabricated and tested and shown to be effective and efficient.

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CHAPTER ONE

1.0 INTRODUCTION

In design and fabrication of equipment to determine the angle of repose of grain, we should take the granular materials into consideration

The term granular materials refer to grains, seeds and fruits. This granular materials posses frictional properties.

The physical properties of these materials influence the angle of repose, such as the grain size, shape, moisture content, density of the material.

When granular materials is been poured on a plane surface it will form an heap and will not be exactly conical, there will be tendency for some materials to roll down from the top and collected at the base, given a greater angle at the top and a smaller angle at the bottom, the angle at which grain well side is determined as the angle of repose of grain.

One of the most basic examples is a pile of sand. If sand is poured slowly onto a pile it will form at a specific angle to the horizontal surface beneath the pile, which is the angle of repose any additional grains added piles down its surface.

CHAPTER ONE

1.0 INTRODUCTION

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Another example is a sandy embankment along a stream. If this is a the angle of repose, which it often is, grains on the surface will slide down very easily and some times spontaneously.

The simple method to access the behavior of material of granular material is to measure the angle of repose, if a solid is poured on to a plane surface it will form an approximately conical heap and the angle between the sloping side of the cone and the horizontal is angle of repose when determined in this manner it is referred to as dynamic angle of repose or the poured angle.

The force of static friction must be over come before granular materials can flow easily once the force flow has begun, the dynamic requirement for continued flow can be estimated.

Although, some engineers referred to angle of repose as the angle for internal friction but (steward 1984) has shown that for a granular material that he tested (sorghum grain) the two angles are different and the use of one in place of the other may introduce an error in design.

Angle of internal friction between granular materials when we are determining angle of internal friction, in angle of repose there is no friction between the granular material. Coefficient of friction is between granular materials is equal to the tangent of angle of the internal friction for the materials.

1.1 Angle of Repose

The angle of repose is the angle with the horizontal at which the materials will stand when piled (mohsenin, 1978). Angle of repose are of two types mainly Dynamic angle of repose is related to a situation where a bulk of the materials is in motion such as the movement of solid discharging from the bin ad hopper. It is more important than the static angle of repose.

Static angle of repose is taken up by a granular solids about to slide upon itself.

1.2 Different type of grains

1. maize
2. Tiger nut
3. Soyabeans
4. Bambara nut
5. Milled local rice
6. Cow pea
7. Acha
8. Millet
9. Ground nut (shelled)
10. Ground nut (unshelled)

11. ground

1.3 Back Ground of the Study

To determine angle of repose of grain when it is be poured on a plan surface, the angle at which the grain will side.

To determine the angle of repose of granular material an equipment have to be fabricated for easy determination.

1.4 Objective of Study

Design and fabrication of equipment to determine angle of repose of grain.

1. To design the equipment to determine the angle of repose of grain
2. To determine accurately the angle of repose of selected materials.

1.5 Justification of Study

In designed fabrication of equipment to determine angle of repose of grain, the angle of repose and angle of internal friction have application in problems of flow of granular materials encountered in the design of gravity and force flow equipment.

Angle of repose and the internal angle of friction have to be taken into consideration.

Bins and hoppers constitute most items of equipments in the handling of granular materials.

Properly designed bins are known volume of bulk solid and to feed it at the prescribed rate at the required time. An improperly designed bins may cause obstruction to flow, erratic flow, development of dead zone resulting in degrading of solid, segregation and several other problem.

For example in the design of groundnut shelling machine, the designer neglect the angle of repose of ground nut and the machine could not effectively perform its designed job, modification was made on the machine ad the angle of repose was taken into consideration and the efficiency of the machine increased.

1.6 Statement of Problem

In design and fabrication of equipment for the determination of angle of repose, the angle of flow have to be taken into consideration. Improper measurement may cause obstruction to flow of grain.

1.7 Scope of Study

This project work includes the study of concept of friction for granular materials to flow without any obstruction.

CHAPTER TWO

2.0 LITERATURE REVIEW

Angle of repose may vary from about 20^0 with free – flowing solid to about 60^0 with solid with poor flow characteristics. In extreme cases of high agglomerated solid, the angle of repose of up to 90^0 can be obtained. Generally, materials which contains no particle smaller than 100μm or 10^{-4}m has a smaller angle of repose, if the angle of repose is large a loose structure is formed initially and the material subsequently consolidate if subjected to vibration.

2.1 Methods of measuring angle of repose of granular materials

Kramer's method

Kramer (1994) studied the angle of repose for milled rice using a wooden frame full of rice mounted on a tilling top drafting table. The table was tilted until the rice began to move leaving an inclined surface. The angle of inclined surface was then measured as the angle of repose for that particular sample. The device for measuring angle of repose of grain is as shown fig 1.0

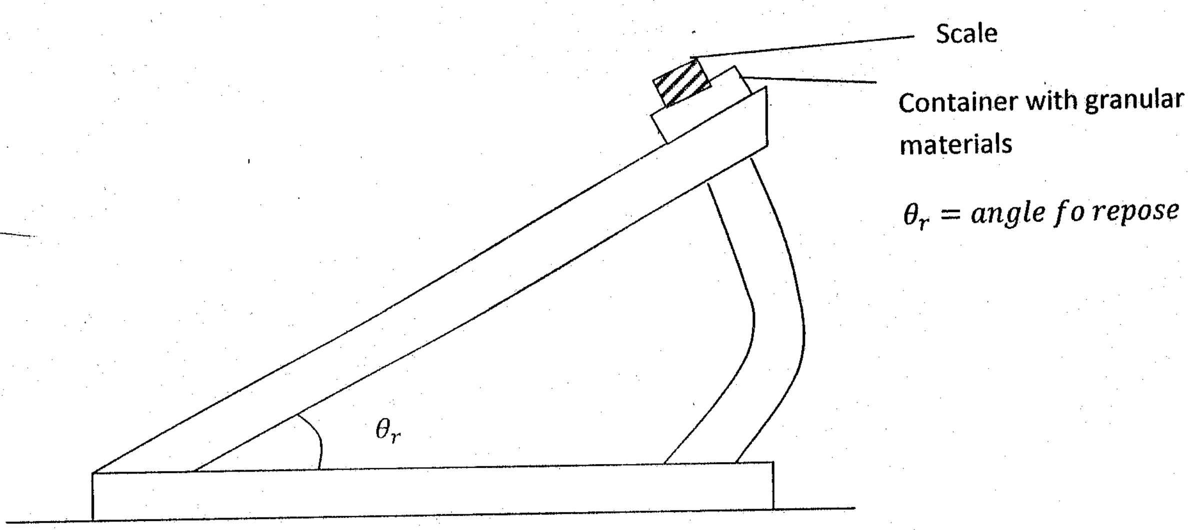


Fig 1.0: Simple device for measuring angle of repose of grains

2.1.1 Fowler and wyatt method of measuring an angle of repose of grains.

Fowler and wyatt made use of apparatus which consisted of a circular platform immersed in a box filled with the granular solid with a glass window. The platform has three adjustable legs and surrounds by a metal funnel leading to a discharge hole. Fowler and wyatt apparatus presented as fig 1.1

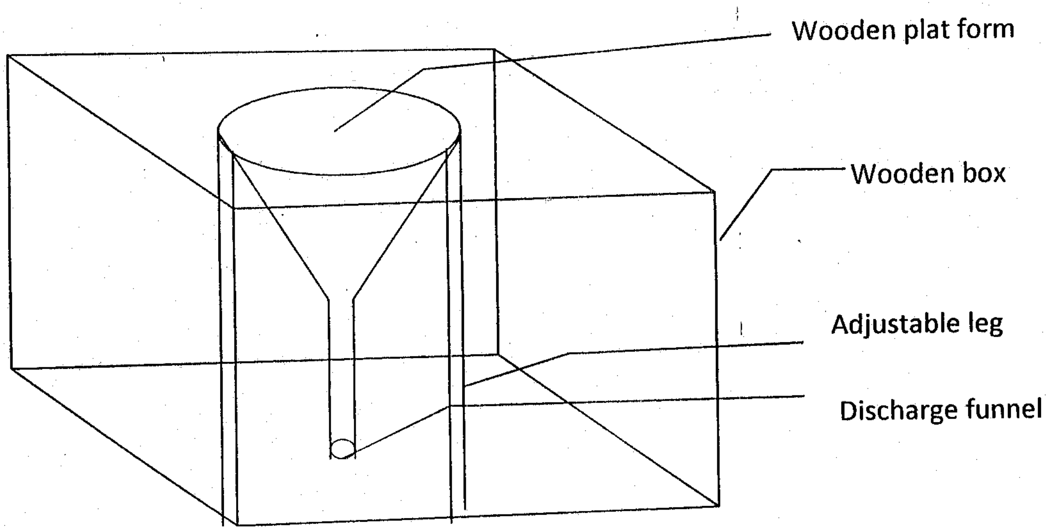


Fig 1.1 Fowler and Wyatt Apparatus

2.2.0 Concept of Friction

Friction is the name given to force that oppose the relative sliding motion of bodies in contact with one another. The frictional force acting between surfaces of rest with respect to each other are called force of static friction. The friction force between surface with relatives motion is called force of kinetic friction.

Coefficient of friction F is the ratio of the force of friction F, and the force normal to the surface of contact W it is given as $f = \frac{F}{W}$ (1)

I. The friction force may be defined as being compose of two main components; a force required to deform and some times shears the asperities of the contacting surface and a force required to overcome adhesion and cohesion between surfaces.

II. The frictional force is not dependent on the surface roughness except in extreme very fine and very rough surface.

III. The frictional force depend on the nature of the materials in contact.

IV. The frictional force depends on sliding velocity of the contacting surface because of the effect of velocity on the temperature of the contacting materials.

2.3 Law of Friction

I. Friction force depends on the nature of the materials in contact due to the increasing need of angle of repose and internal angle of friction of granular materials in the designs of bins, hoppers and silos

II. Frictional force is largely dependent on sliding velocity

III. Frictional force is proportional to normal load.

IV. The frictional force f is directly proportional to the normal reactions

2.4 Comparison of Angle of Repose and Angle of Internal Friction

Angel of repose is the angle with the horizontal at which the material will stand when piled.

2.5 Angle of Internal Friction.

In angle of repose granular material will stand without any friction, in angle of internal friction there is friction between the granular material.

Lorenzen (1957) attempted to relate the angle of repose $\emptyset_1$, and of internal friction, $\emptyset_1$ with the hope that a simple test of repose angle determination would yield the value of $\emptyset_1$ the two angle almost run parallel to each other for moisture content. But no single relationship existed where $\emptyset_1$ could be estimated from $\emptyset_r$.

Triaxial tests were used by other investigators which are more elaborated because of the difficulty of predicting the angle of internal friction from the angle of repose. Stewart (1984) applied a triaxial compression test which was developed for studying the shear properties of soil, to the study of sorghum grain and the effect of density as well as moisture content on internal angle friction . fig 1.5 shows the triaxial compression test apparatus. Lorenzen (1957) investigated the effect of the same factors on internal angle of friction of wheat, rice, corn barley and sawdust using a triaxial compression. Apparatus.

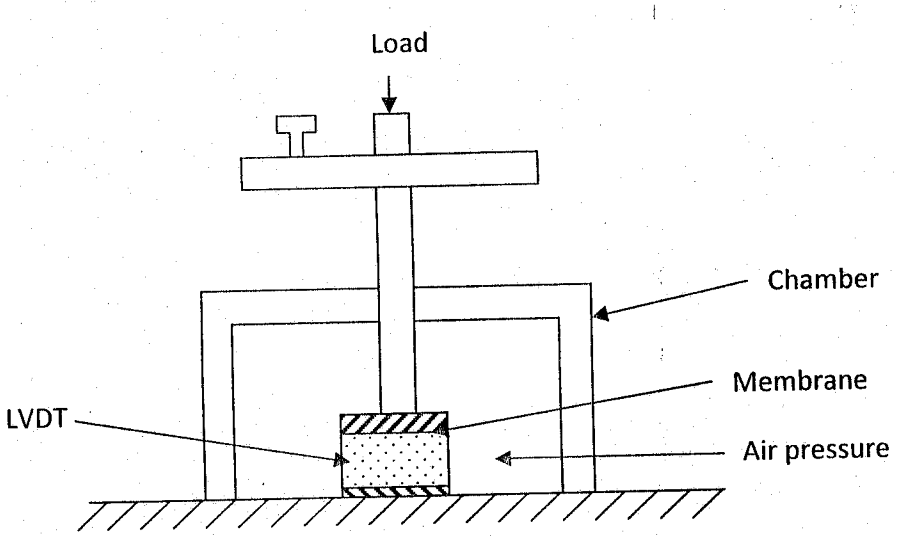


Fig 1.2: Schematic diagram for application of triaxial compression test

2.6 Determination of Angle of Internal Friction $\emptyset_1$

A measure of frictional forces between the granular materials is the angle of friction in predicting the lateral pressure on a retaining walls in storage bins or design of bins and hoppers for gravity flow, the co-efficient of friction between granular materials is needed as a design parameter.

For example, in design of shallow bins, rankine equation (equation 2) is used,

$$\delta_3 = wy\, tan^2[45 - {}^{\emptyset_1}/_2] \qquad (2)$$

Where:

δ_3 is the lateral pressure against the wall at point y feet below the top of the wall w is the weight density of the materials in ${}^{Ib}/_{ft^3}$ and $\emptyset_1$ is the angle of internal friction.

In design of deep bins and other similar storage structures the pressure ratio k. referred to the ratio of the lateral pressure δ_3 to the vertical pressure γ_1 at a given point in the material is needed.

$$k = \frac{\delta_3}{\delta_1} \qquad (3)$$

K can also be found from the angle of internal friction as seen from the expression

$$K = \frac{[1-\sin\emptyset_1]}{[1+sin\emptyset_1]}$$

The vertical pressure causes a column action while the lateral cause a bending action on the wall. In grain bins when the height of the materials in the bin exceed a certain limit [2 to 2.5 times the bin diameter]. No increase in the bottom pressure can be detected with increase depth of the grain this indicate that the wall. Must be supporting the additional [1919] and others have stated that constant but vary with the type of and the geometry of the bin as well as the depth function and cohesion properties and moisture content of the material "the influence of this various factors on pressure ratio k is illustrated by the Janssens's equation (equation 4) given for the lateral pressure δ_3 in deep bins

$$\delta_3 = \frac{wr}{fs}\left[1 - e^{-kfsh}/_R\right] \qquad (4) \qquad \text{(Janssen's equation)}$$

Where R = hydraulic radius of the ratio of cross sectional area to the circumference w = weight of the material

fs = static co – coefficient of the material against the wall

h = depth to the material.

The pressure ratio k is obtained either directly by pressure measurement of full – size or model bin or the use of triaxial compression test chamber and the mohr's circle. According to mohr's theory a material under stress fails along the plane at which a certain combination of normal and shear stress occurs from fig 1.3b it shows the three principal planes major, intermediate and minor in order of decreasing magnitude of direct stress through a point 0 on the granular.

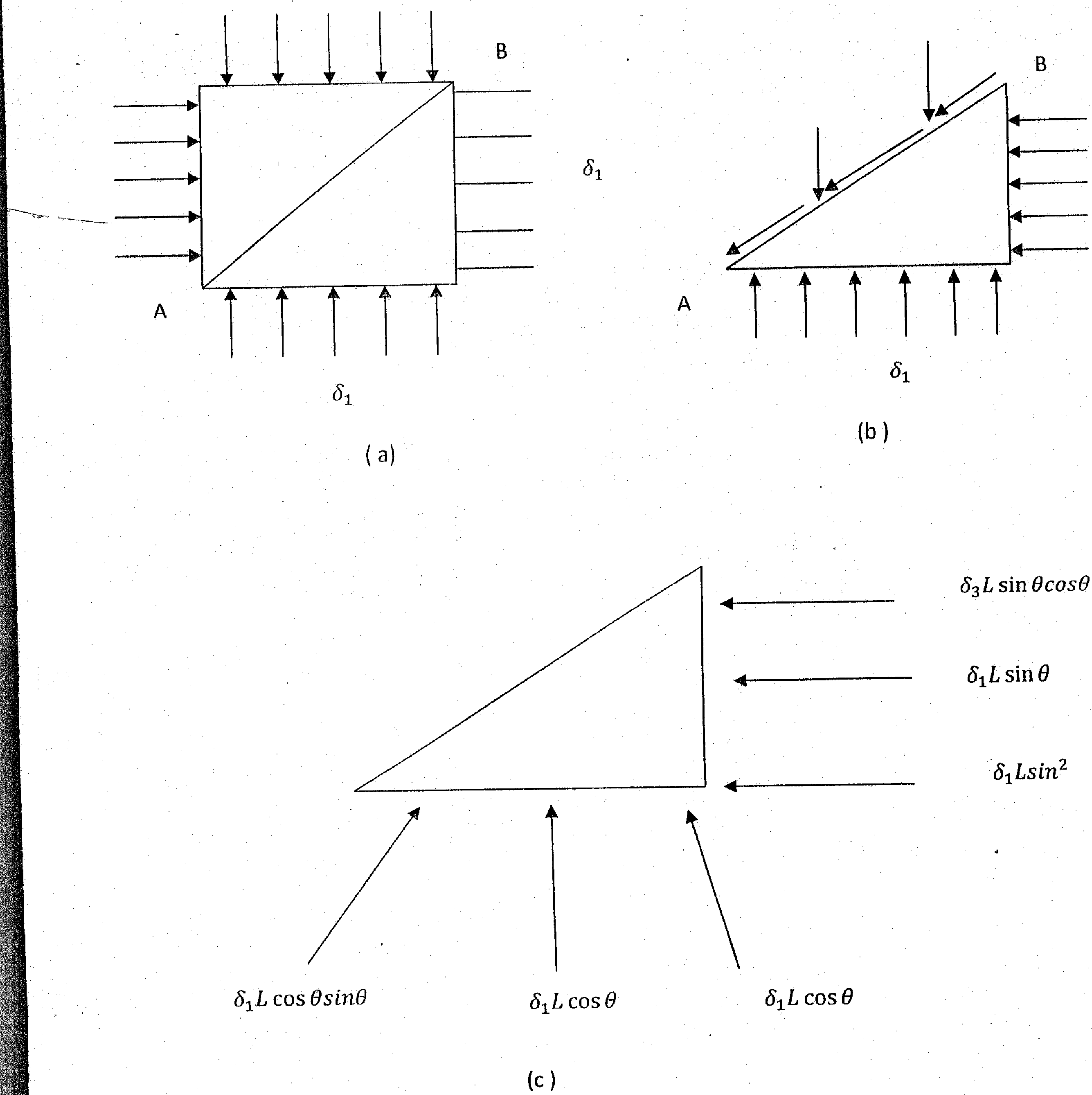


Fig 1.3: show direction of force

δ_1. b) stress acting on cubical unit in a granular mass and a shear plans ab from this unit.

(C) Equilibrium of force direction normal and parallel to ab.

If the length of A_1 B is designated by L, the forces acting in the side of the element will be as shown in fig 1.26 equilibrium of those forces in the direction normal to AB yield the equation for normal direct stress δ and the shear T as follows

S = $\delta_1 \cos^2\emptyset + \delta_3 \sin^2\emptyset$ (5)a

T = $(\lambda_1 - \delta_3)\sin\theta\cos\theta$ (5)b

The two equations above were obtained after dividing through by L

The graphical representation of stresses of any point in the granular mass can be given by a mohr's circle as shown in fig 1.3 from the following relationship can be deduced.

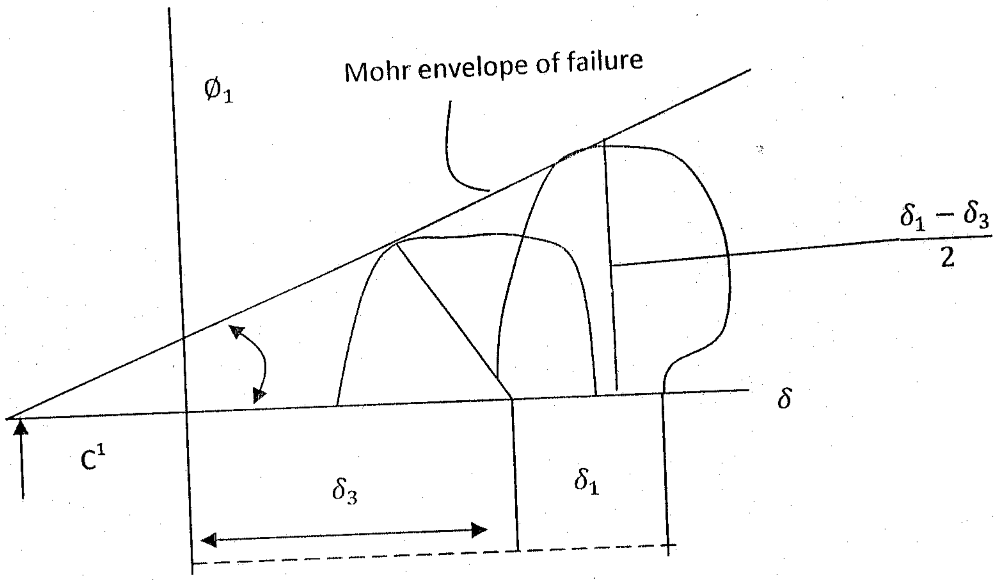
$$\sin\emptyset_1 = \frac{(\lambda_1-\delta_3)}{(\delta_1-\delta_3)} = \frac{\delta_3}{\delta_1} = \frac{(1-\sin\emptyset_1)}{(1+\sin\emptyset_1)} \quad (6)$$

The value of δ_1 and δ_3 can be obtained by a triaxial compression text where a minor principal stress δ_3 will be equal to chamber pressure and the major principal stress δ_1

will be equal to the chamber pressure plus the intensity of axial thrust (Taylor 1948).

Fig 1.3 mohr circle and mohr envelope of failure.

Ac[1] shows the orientation of a plane of failure while AC shows the orientation of a stable plane.



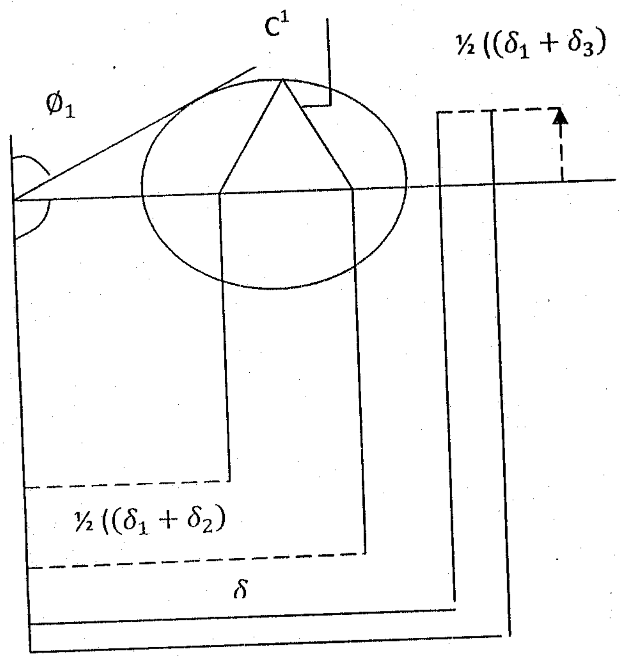


Fig 1.4: Shows the orientation of a stable plane

In the established mohr envelope, at least two set of data needed from which semi – circle given in fig 1.3 can be described and the tangent line established from this graphical method, shear strength and its angler of repose can be determine. This two parameters may also be calculated from the equation of mohr's circle

$$cos\emptyset = \frac{\left[C^1 + \delta_3 + {(\delta_1 + \delta_3)}/{2}\right]}{{(\delta_1 - \delta_3)}/{2}} \tag{7}$$

After simplification, the above yield of the equation of mohr's circle as

$$\delta_3\left[{\delta_1}/{\delta_3} - 1\right]CSC\emptyset_1 - \delta_3\left[{\delta_1}/{\delta_3}\right] + 1] - 2C^1 = 0$$

Having two sets of data, equation 9, can be written twice and solved simultaneous to obtained d $\emptyset_1$ and C^1 from this two parameters, the value of C in fig 1.3 can be determined.

C = C^1 Tan Ø. The parameter, C is usually taken as cohesion of the granular material, however some authorities consider C as the experimental is assumed cohesionless, i.e C = 0 then,

$$K = \frac{[1 - \sin\emptyset]}{[1 + \sin\emptyset]} \tag{8}$$

Having known the value of k and by change of subject formular, the angle of internal friction, Ø is calculated from equation 10. As $\emptyset = sin\frac{(1-k)}{(1+k)}$ (9)

2.7 Application of Repose Angle And Angle of Internal Friction

Granular materials have problems of flow in a bin and hopper, the angle of repose and angle of internal friction have application in flow of granular materials. For example, when designing a bin and a hopper the angle of friction between the grain and the wall of a bin or hopper must be put into consideration.

2.8 Effect of Physical Properties of Granular Solids on Angle of Repose and Internal Friction.

Grain shape, size density and moisture contents have effect on angle of repose and angle of internal friction. The rolling resistance or maximum angle of stability in rolling agricultural materials with rounded shape may serve as a useful design information are example is the gravity conveying of fruits and vegetables.

Its is interesting to know that canary seed (millet) which has an elongated shape with shape factor of n =1.78 predicts a higher angle of repose while the experimental values showed the angle begin less than that of wheat at any moisture contents.

2.9 Types of Flow in Bin and Hoppers

Using shear apparatus considered the flow of properties of granular materials along the bin and hopper.

i. Funnel – flow: Here the solid flow towards the outlet in a channel formed within the solid it self. The solid surrounded this channel is at rest and has a tendency to spoil, cake or oxidize, if it is not emptied out.

ii. Mass flow: mass flow is on e in which the cone is sufficiently steep and the surface coefficient is small the channel expand from the outlet upward along the wall of the bin and all the solid is in motion. Since in mass flow, the flowing channel of the granular materials coincides with the wall of the hopper the shape and frictional effects of the wall have a great influence of flow. In an ideal mass – flow, there is no dead zone and all the solid in the hopper are in motion whenever any of it is drawn out of the outlet.

2.10 Gravity of Flow in Bin and Hopper

The major items used in the handling of granular material are bins and hoppers. Properly designed bins are to hold a known volume of bulk solid and feed it at a prescribed rate of required time. Improper design bins and hopper may cause obstruction to flow, erratic flow, development dead zone resulting in the degradation of solid, segregation and several other problems. Jenike (1964) developed a direct shear test apparatus for determination of flow properties of granular materials.

2.11 Flow Functions and Flow factors

Some of problems associated with gravity flow of granular material from a bin or hopper are eratic feeding flooding, sticking of the wall, ad formation of obstruction such as "piping" and "arching". Te strength of the solid depends on its moisture content, surface roughness and large the degree of consolidation greater consolidation result in greater strength.

Flow function, ff is the relationship between unconfined yield pressure of a solid and consolidated pressure.

$$\delta_1 = f(\delta_1) => FF = \frac{d\delta_1}{d\delta_2} \qquad (10)$$

In order to obtain the function curve of a solid, several share test are conducted for several consolidation land, W_C and the resulting $\delta_1 and\ \delta_c$ are plotted as shown in fig 1.8 Jenike, 1964 showed that for a given hopper, there exist a critical line such that as long as the floor function curve of the solid lies below this line, the strength of the solid is insufficient to support arch and there will be no obstruction to flow. The critical line is referred to as flow factor, flow factor denoted by ff is the ratio of the critical major consolidating pressure, δ_1 to critical unconfined yield pressure, δ_c determined experimentally.

FF = [δ_1] δ_c critical = (f_1/f_c) critical J this is the condition at which bulk of materials is just on the point of forming and obstruction of low conversely, in a free flowing solid,

δ_c = f(δ_1) < δ_c critical = (1/ff) δ_1

$$\frac{\delta_1}{\delta_c} = ff$$

Flow function ff depends on material only ff depend on both the materials and the hopper geometry. Jenike, 1984 classified granular solid according to their limiting flow function given by the letter ff.

Ff < 2 – very cohesive and non – flowing

4 > ff > 2 cohesive

10 > ff > 4 – easy – flowing

Ff > 10 - free flowing

Graph of unconfined yield pressure δ_c against major consolidating pressure δ_1

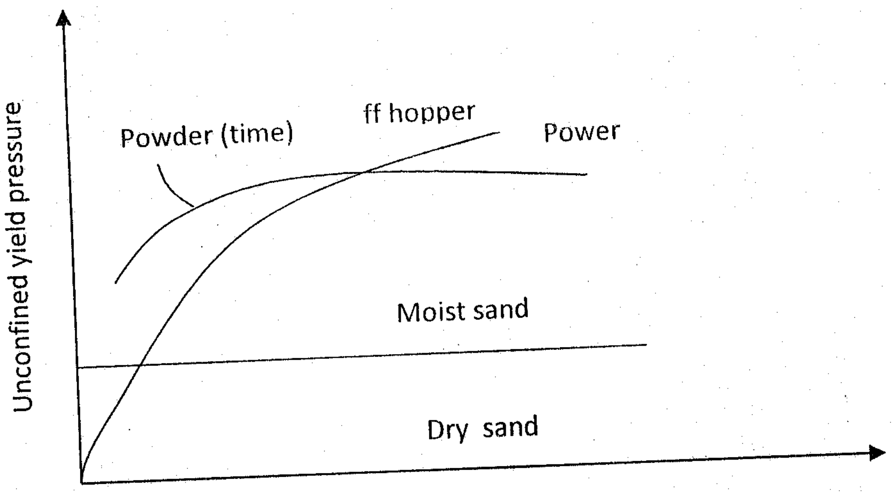


Fig 1.5: Critical flow factor ff of a hopper super imposed on flow function several solids.

2.12 Critical Dimension of Hopper Opening

To determined the critical dimension of hopper opening, failure condition must be established for two basic obstructions, namely "arching" – where no flow take place and "piping" – where may be reduced or limited. Fig 1.a shows the free body diagram of a granular solid with bulk density, w. forming an arch with uniform thickness T. let B denote the diameter of circular hole or the width of the slot with length, l for small arcs, the equilibrium of force resulting from the weight of this mass acting down ward and the vertical component of force due to compressive pressure p in the arch acting upward yields.

WBC T = 2PLT cos α sin α (11)

$$B = \left(P/_w\right) \sin 2\alpha (\text{since } 2 \sin\alpha \cos\alpha = \sin 2\alpha)\ \textit{for slot.}$$

$$w(\pi/_4)B^2T = P\pi BT \cos\alpha \sin\alpha \quad (12)$$

$$B = \frac{2p}{w}(\sin 2\alpha) \quad (13)$$

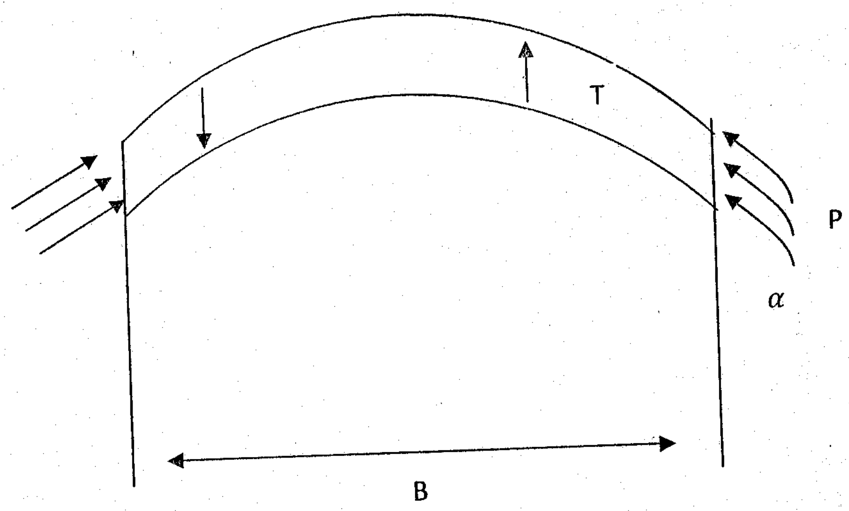


Fig 1.6: Shows free body diagram of mass of granular material forming an arch.

for circle free body diagram of mass of granular material forming an arch.

From the analysis, John son and Colijin (1964), suggested that in order for failure to occur, the major compressive pressure p should be equal to unconfined yield strength, δ_c, substituting δ_c for p and assuming sin 2α = 1 in equations 13 and 14

=>B >= $\frac{\delta_c}{w}$ .... for slot opening and B >= $^{2c}/_w$.

2.13 Physical Properties of Agricultural Material

physical properties are the size of grains and the moisture contents

the grain used for the determination of angle of repose are

maize, groundnut (unshelled), ground nut(shelled) soya beans, millet, milled local

rice, bambara nut, acha and cowpea.

Table 1.10 Physical properties of the investigated grains

S/no	Items	Average major diameter (mm)	Average minor diameter (mm)	Average intermediate (mm)	Moisture content %
1	Maize	10.5	5.1	8.1	12.4
2	Tiger nut	8.3	5.3	6.9	12.5
3	Soya beans	8.2	4.9	6.2	12.2
4	Bambara nut	10.8	8.3	9.0	12.8
5	Milled local rice	2.1	1.7	2.1	13.8
6	Cowpea	7.7	4.5	6.2	11.2
7	Acha	1.0	0.7	0.8	13.4
8	Millet	3.3	1.9	2.1	10.8
9	Groundnut (shelled)	13.1	6.6	6.8	18.6
10	Groundnut (unshelled)	24.3	10.4	11.5	11.0

Table 2.0

The results obtained during the analysis is as presented in the table below.

Gravimetric method of determining moisture content of selected agriculture materials.

S/No	Selected agriculture material	Initial weight Xg	Final weight Yg	Mass of water removed Zg	Moisture content (M.C)%
1	Maize	5.00	4.38	0.62	12.40
2	Tiger nut	5.00	4.37	0.63	12.50
3	Soya beans	5.00	4.39	0.61	12.20
4	Babara nut	5.00	4.36	0.64	12.80
5	Milled local rice	5.00	4.31	0.69	13.80
6	Cowpea	5.00	4.44	0.50	11.20
7	Acha	5.00	4.33	0.67	13.40
8	Millet	5.00	4.46	0.54	10.80
9	Groundnut (shelled)	5.00	4.07	0.93	18.60
10	Groundnut (unshelled)	5.00	4.45	0.45	11.00

CHAPTER THREE

3.0 MATERIAL AND METHODS

The materials used for fabrication of the apparatus (Fowler and Watt type) for determining angle of repose are wood, plastic, glass and a metal sheet.

METAL: A metal is define in chemistry as an element that yield positively charged ions in aqueous solution of its self.

Metals are in general, these substances that have a peculiar lustre and hardness can conduct heat and electricity opaque and posses certain mechanical properties. Other notable characteristics of metal include; ability to resist tensile, compressive, torsional and shear stress, malleability hardness, toughness, durability and fabrication or workability,

WOOD: There are two classes of wood, deciduous tree (hard wood) soft wood (ever green). Hard wood.

3.1 Physical and Chemical Properties of the Constructional Materials

Wood:

a) Constituent: all wood consist of the following component

i. Moisture content: wood shrinks as it losses water and wells as its absorbs moisture

ii. Resistance to decay: Some species of both hard wood and soft wood have high resistance to decay and can be used under condition. Where decay hazards exists.

iii. Seasoning: This is the process of drying timber, seasoning could either be by air drying a kiln – drying. Advantages of kiln dry over air dry are: greater reduction in weight, control of moisture content to any desired value, reduction in dry time, killing any fungi or insect, setting the resign in resinous wood and less degrade.

Degrade: This is the loss in quality drying seasoning of the timber through

i. Unequal shrinkage e.g honey comb warp, loosening of knot and collapse.

ii. Action of fungi, such as mould, strain and decay.

Physical and mechanical properties of glass physical and mechanical properties of glass vary with composition and cover the following ranges.

1. Light transmission: Commonly used glasses transmit 85^0C to 95% of visible light. Most glasses are impervious to ultraviolent light.
2. Workability : glass can be fabricated into desired shape, it can be cast, pressed, rolled, blown polished and ground.

3. Strength: The smaller the cross – section of glass, the greater will be unit if length – glass fibre have tensile strength to 10342. SN/m^2 where as 6.45cm^2 cross section of glass has a strength of 34.48mn/m^2

Plastic:

Plastic consist of the following components

i. Malleability: Plastic can be melted when it pass through heat, it can be deformed into any shape.

ii. Ductility: Plastic can be broken when it is in solid from.

iii. Workability: Wood can be fabricated into desired shape.

3.2 Data of Constructional procedure

What is important to know in the construction field is data on those physical, chemical and mechanical properties that influence the use of metallic material in construction this include: melting point, tensile strength, coefficient of expansion, corrosion resistance to various chemicals, workability ease of handling in both fabrication and reaction to weather.

3.3 Determination of Angle of Repose

The Materials (grains) used in Determining the Angle of Repose:

1. Maize

2. Tiger nut

3. Soya beans

4. Bambara and

5. Milled local rice

6. Cowpea

7. Acha

8. Groundnut (shelled)

9. Groundnut (unshelled)

Comparison of the abundance of various metals and the relative difficulties in obtaining them as metals give interesting and valuable insight into future technological development the phenomenal development of knowledge or the physical science and their industrial application which as taken place in the few decades will surely leads to new materials and new structural methods in the construction industry of tomorrow.

In the development of this apparatus for measuring angle of repose of granular material a piece of metal plate is fabricated as a funnel through which granular material that roll down flow into the receiver provided underneath, iron rod and flat bar are used in the construction of the table.

Method used in determining angle of repose Fowler and Wyatt method:

$$\theta_r = tan^{-1} \frac{2(H_C - H_P)}{D_P} \qquad (1)$$

H_C = height of cone from datum

H_P = height of flat form

$(H_C - H_P)$ = Height of cone

D_P = Diameter of circular flat form.

1.. Maize: Botanical name zeamays

Family name: gramineae

Shape: Truncate/mc = 12.4%

Angle of repose, $\theta_r = tan^{-1} \frac{2[44.5-39]}{23.0}$

= $\tan^{-1} 0.4783$

= 25.6^0

2. Tiger nut

Shape: oblong cylindrical /m.c = 12.5

Angle of repose $\theta_r = tan^{-1}\frac{2[46.7-37]}{23.0}$

$tan^{-1} = 0.6676$

$= 33.7^0$

3. Soya beans

Shape: Oblate/m.c = 12.2%

Angle of repose, $\theta_r = tan^{-1}\frac{2[45.7-39]}{23.0}$

$= tan^{-1} 0.5826$

$= 30.2^0$

4. Bambara nut

Shape: kidney shape/obvate/m.c = 12.8%

Angle of repose, $\theta_r = tan^{-1}\frac{2[43.9-39]}{23.0}$

$= tan^{-1} 0.4261$

$= 23.1^0$

5. Milled local rice m/c = 13.8%

Angle of repose, $\theta_r = tan^{-1}\frac{2[46.2-39]}{23.0}$

tan^{-1} 0.6261

= 32.1^0

6. Cowpea m/c = 11.20%

Angle of repose, $\theta_r = tan^{-1}\frac{2[45.0-39]}{23.0}$

= tan^{-1} 0.5217

= 27.3^0

7. Acha (Hungary rice)

Shape round

m.c - = 13.40

Angle of repose, $\theta_r = tan^{-1}\frac{2[47.5-39]}{23.0}$

= tan^{-1} 0.7391

= 36.5^0

8. Millet (finger millet)

Shape: Elongated ellipsoidal/m.c = 10.8%

Angle of repose, $\theta_r = tan^{-1}\frac{2[44.9-39]}{23.0}$

$= \tan^{-1} 0.5130$

$= 27.2^0$

9. Groundnut(unshelled)

Shape: long – cylindrical oblate/m.c = 11.0%

Angle of repose, $\theta_r = tan^{-1} \frac{2[46.3-39]}{23.0}$

$= \tan^{-1} 0.6348$

$= 32.4^0$

10. Groundnut (shelled)

Shaped: Ovate/m.c = 18.6%

Angle of repose, $\theta_r = tan^{-1} \frac{2[46..7-39]}{23.0}$

$= \tan^{-1} 0.6696$

$= 33.8^0$

Table 3.0: Moisture Content of Grain Used for Measurement

S/no	Selected agric material	Initial weight x(g)	Final weight x(g)	Mass of water removed	Moisture content (m.c) %
1	Maize	5.00	4.38	0.62	12.40
2	Tiger nut	5.00	4.37	0.63	12.50
3	Soya beans	5.00	4.39	0.61	12.20
4	Bambara nut	5.00	4.36	0.64	12.80
5	Milled local rice	5.00	4.31	0.69	12.50
6	Cowpea	5.00	4.44	0.56	11.20
7	Acha	5.00	4.33	0.67	13.40
8	Millet	5.00	4.46	0.54	10.00
9	Groundnut (shelled)	5.00	4.07	0.93	18.00
10	Groundnut (unshelled)	5.00	4.45	0.45	11.00

3.4 Material costing.

Table 4.0 the cost of materials used in the development of an apparatus for measuring the angle of repose of grain is represented in the table below.

Materials	Quantity (description)	(cost price ₦)
20 inches plywood	51cm(20 inches)	₦ 2000
3mm thick glass	46cm x 49cm	₦ 3,500
Cylindrical metal funnel	26cm diameter	₦ 3,000
3 ruler	46cm long, 48.3cm long, 63.5cm	₦ 1,800
1 ½" (3.8cm) nail	½ kg	₦ 400
Pipe	46cm	₦ 300
	Total	₦ 11000

CHAPTER FOUR

4.0 RESULTS AND DISCUSSIONS

TABLE 5.0 ANGLE OF REPOSE OF SELECTED AGRICULTURAL MATERIALS

S/no	Selected agric materials	D_p (cm)	H_p (cm)	Hc(cm)	Hc – Hp(cm)	Or (degree)
1	Maize	23.0	39cm	44.5	5.5	25.6
2	Tiger nut	23.0	39cm	46.7	7.7	33.7
3	Soya beans	23.0	39cm	45.7	6.7	30.2
4	Bambara nut	23.0	39cm	43.9	4.9	23.1
5	Milled local rice	23.0	39cm	46.2	7.2	32.1
6	Cowpea	23.0	39cm	45.0	6	27.3
7	Acha	23.0	39cm	47.5	8.5	36.5
8	Millet	23.0	39cm	44.9	5.9	27.2
9	Groundnut (shelled)	23.0	39cm	46.3	7.3	32.4
10	Groundnut (unshelled)	23.0	39cm	46.7	7.7	33.8

4.1 Gravimetry Method of Determining Moisture Content of Selected Agric Materials

Table 6.0: Gravimetry method of determining moisture content of selected agric materials

S/no	Selected agric material	Initial weight xg	Final weight xg	Mass of water removed xg	Moisture content (m.c) %
1	Maize	5.00	4.38	0.62	12.40
2	Tiger nut	5.00	4.37	0.63	12.50
3	Soya beans	5.00	4.39	0.61	12.20
4	Bambara nut	5.00	4.36	0.64	12.80
5	Milled local rice	5.00	4.31	0.69	12.50
6	Cowpea	5.00	4.44	0.56	11.20
7	Acha	5.00	4.33	0.67	13.40
8	Millet	5.00	4.46	0.54	10.00
9	Groundnut (shelled)	5.00	4.07	0.93	18.00
10	Groundnut (unshelled)	5.00	4.45	0.45	11.00

4.2 Discussions

The moisture content and the angle of repose of selected agricultural material were taken shown in the table.

4.3 Observation

When measuring the angle of repose of grain to ensure that the grain is properly pile and avoid shaking the equipment so that you can get accurate measurement.

Ensure that the ruler is straight when measuring angle of repose of grain.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Comparing the result after measurement with the work of some other people both in Nigeria and abroad i.e from literatures the difference of $\pm 0.96^0$ to $\pm 9^0$. It can therefore be concluded that the development apparatus can accurately measure the angle of repose of selected grains which have storage equipment.

5.2 Recommendation

During the course of the project work, limitation were faced and slight problems were encountered which resulted to the deviation of some of the measured and calculated parameters from literature values, for instance, the replacement of the cathetometer with a graduated rule to measure the weights of the cone formed by materials.

Secondly, the grain profile was assumed to be linear, but in the actual sense, it is parabolic, hence mathematical deviation using the parabolic curve function should be used to reduce the error to minimum and corresponds with the standard values.

The discharge pipe of the funnel should be made higher than it is to allow the free flow or discharge of the material to be measured to form a perfect cone.

Lastly, the size of the box should also be reduced and corresponding reduction in the size of the other components, because of the cost of filling the box is high and the reduction in the size has an effect in the measurement of repose angle.

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