EXPERIMENT # 1: MATERIALS PHYSICAL PROPERTIES AND TESTS

1. MATERIALS' VOLUMETRIC MASS

Materials' volumetric mass represents the mass of unit volume and it is quoted in International System in kg/m^3. In the case of building materials, following densities can be established: *real density* ; *apparent density* a; *bulk density* g; *pile density* s.

1.1. Density (real)

Real density of a solid material is the ratio between the mass and the real volume of that solid:

$$\rho = \frac{m}{V} \left(\frac{Kg}{m^3}\right)$$

By *real volume* V, one can understand the volume from which the pores were eliminated. Because building materials have a porosity grade (excepting superior class glass, laminated steel and some polymers), in order to determine the real volume, it is necessary to destroy the structure of the material in order to eliminate all its pores. This can be realized by pulverization of the material in fine particles having dimensions smaller than 0.2 mm. The obtained material is homogenized and drayed out in the stove at 105-110 ^{0}C, until between two successive weightings, made at a time interval of 4 hours of drying and 1 hour of cooling, the mass remains constant.

From the obtained material, a mass of m= 2…15 g is weighted and introduced into a graduated cylinder. For materials' real volume determination, a graduated burette is used, which is to be filled up with an inert liquid regarding to the material (such as: water, gasoline, etc). A liquid volume V_b is released from the burette into the graduated cylinder, and then by use of a metallic thin rod, the powder is mixed, so that the air between particles is eliminated and the liquid penetrate the whole powder. The liquid level from the graduated cylinder is denoted by V_c. The material's real volume is determined by the following relationship:

$$V = V_c + \mathrm{V_b}\ (\mathrm{m}^3)$$

Knowing the mass m and the real volume V of the material, the real volume mass will be determined.

1.2. Apparent Density a

Apparent density a : represents the ratio between material's mass and its apparent volume V_a (in which the pores are also included):

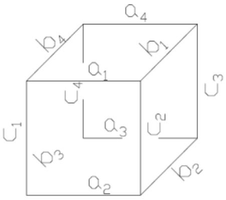
$$\rho = \frac{m}{V_a} \left(\frac{Kg}{m^3}\right) \qquad\qquad V_a = \mathrm{V} + \mathrm{V_{pores}}$$

The mass m is determined by draying out the material, at 105-110 0C into the specific stove and simply weighting it. The apparent volume is determined according to the one of the following methods, regarding to the shape of the sample:

Method A. Determination of Apparent volume by Direct Measurement of Samples' Dimensions

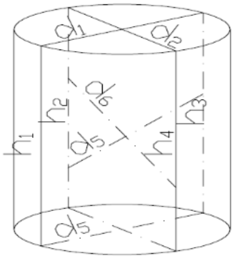
This method can be used only for samples that have a regulated, known geometrical shape.

For *apparent volume* determination, the sample is measured in the following way: for cubic and prismatic shapes' like samples all edges are to be measured a_i, b_i, c_i, where i= 1…4 and mean a_i, b_i, c_i values are computed such as:



$$\mathrm{a} = \frac{1}{4}\sum_{i=1}^{i=4} a_i$$

For cylindrical samples, two perpendicular diameters are measured at their basis and also to the middle of their height di, where i= 1…6. The four heights hi, i= 1…4, are also measured:



$$\mathrm{d} = \frac{1}{6}\sum_{i=1}^{i=6} d_i \quad and \quad \mathrm{h} = \frac{1}{4}\sum_{i=1}^{i=4} \mathrm{h}_i$$

Having all geometrical dimensions the *apparent volume* of the sample can be obtained.

Method B. Apparent Volume Determination By Measuring The Dislocated Water Volume

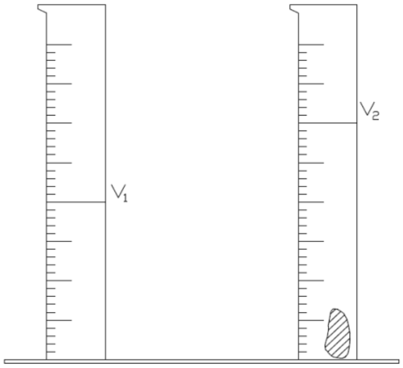
This method is used for irregular shape-like samples. The drayed sample is weighted, than it is covered by a thin paraffinic layer, or it is saturated with water. The water saturation is done at normal pressure introducing the sample into distil ate water up to ¼ of its height for two hours and then the water level is raised up to ¾ of samples' height, for another 24 hours. After this, the sample is covered by distillate water and kept in this way another 24 hours. At this time end, the sample is rinsed out by a wet piece of cloth; it is weighted and introduced again into the distillate water. The weighting procedure is to be repeated from 24 hours to 24 hours until the weighted masses dose not differ more than 0.05%. This method is not so accurate because the open pores of the tested sample do not retain the water during the extraction of the sample from the water. In the case of using the paraffin method, the drayed out sample is weighted, obtaining its mass m, then the sample is immersed into the melted paraffin solution for 1-2 seconds and then it is extracted and cached from another place and again immersed into paraffin. The paraffin coat obtained after cooling does not permit the water to pass into sample's pores. The paraffined sample is weighted, thus obtaining the mass m_1. The difference (m_1-m) represents the mass of the paraffin layer. Knowing the paraffin density, ρ =0.9 g/cm3, the paraffin volume can be determined:

$$\mathrm{V}_p = \frac{m_1 - m}{\rho}\ (cm^3)$$

The apparent volume of the sample is obtained extracting from the apparent volume of the paraffined sample V_t, the volume of the coat of the paraffin V_p:

$$V_a = V_t - \mathrm{V_p}\ (\mathrm{cm}^3)$$

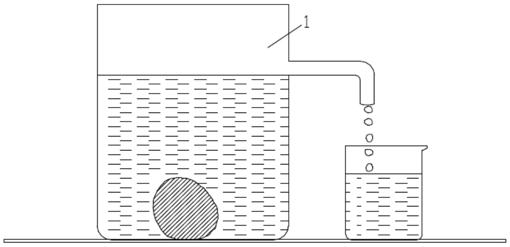
After preparing the sample by means of one of the upper presented ways, the apparent volume can be established using a graduated cylinder or, for bigger samples, a vessel with a lateral hole. In the case of small samples with irregular shapes, the determination is made by help of a graduated cylinder of 250 - 500 cm^3. For this, a liquid volume of V_1 is poured into the graduated cylinder and then, the sample is carefully introduced too. The water level will rise up to the level V_2 in the graduated cylinder. The rising of water level equals to the apparent volume of the sample, denoted V_a.



Graduated cylinder

$$V_t = \mathrm{V_2} + \mathrm{V_1}\quad (cm^3)$$

For big samples, having irregular shapes, the apparent volume is determined by use of a vessel with a lateral orifice. For this case, in order to calibrate the determination device, the water is introduced first over the orifice level and the excess water is let to pour through the orifice. Then, the saturated or paraffined sample is immersed carefully into the vessel, the dislocated liquid is collected into a graduated cylinder and represents the apparent volume of the sample (because water density is 1 g/cm^3).



Lateral orifice vessel

1.3. Bulk Density ρ_g

The bulk density is determined for granular materials (cement, lime, plaster, sand, gravel etc) and represents the ratio between mass of granular material and its bulk volume (which includes its pores volume present in each granule and the volume of free spaces between granules):

$$\rho = \frac{m}{V_g}\ \left(\frac{Kg}{m^3}\right)$$

$$V_g = \mathrm{V} + \mathrm{V_{pores}} + \mathrm{V_{spaces}}$$

For determining the bulk density, cylindrical shaped vessels are used, having a volume of 1 liter, for granular materials with D_{max}=8 mm and of 5 liters for granular materials having

D_{max}=16mm. The value of bulk density is in function of the compaction grade of the material, so that, it is determined by one of the following states: aerated state and compacted state.

Bulk Density – Aerated State ρ_{ga}

The granular material, previously drayed out, is poured, from 10 cm height with a soffit (5 cm height in the case of hydrated lime), into a vessel which has a known volume (V_g) and mass (m_1). The vessel is fulfilled until a peak of granular material is obtained. The material's peak is levelled up by help of a metallic line, and the vessel is weighted (m2). *Bulk density in aerated state* is computed by:

$$\rho_{ga} = \frac{m_2 - m_1}{V_g} \left(\frac{Kg}{m^3}\right)$$

Compacted Bulk Density ρ_{gi}

The granular material, previously drayed out, is introduced into a determination vessel of known mass (m_1) and volume, in three successive layers, after each one, the vessel being bitted 50 times by the table, or vibrated on vibrating table for 50 seconds. For compacting of the last layer, prolong is added to the vessel; after compacting being finished, the prolong is taken away and the filled in vessel is weighted (m_2).

Compacted bulk density is:

$$\rho_{gi} = \frac{m_2 - m_1}{V_g} \left(\frac{Kg}{m^3}\right)$$

1.4. Pile Density s

The *pile density* is determined for materials which can be stored into piles (bricks, wood etc) with the following relationship:

$$\rho_s = \frac{m}{V_s} \left(\frac{Kg}{m^3}\right)$$

where:

m: the material mass, determined by weighting the piles;

V_s: the volume of the pile, determined by mathematical computation by use of piles' dimensions.

2. COMPACTNESS, POROSITY, WATER ABSORBTION AND HOLES VOLUME

2.1. Compactness represents the filling grade with solid matter of the apparent volume of one material:

$$\%C = \frac{V}{V_a}.100 = \frac{\rho_a}{\rho}.100$$

Compactness is the ratio between the volume V of the solid phase (actual volume) and the apparent volume V_a.

Because $V \le V_a \Rightarrow C \le 100\%$

Materials without pores (glass, steel, some polymers etc) have maximum compactness, that is: C=100%

The compactness is determined by mean of the real and the apparent densities.

Table 1. *Compactness and porosity of some materials*

Material	ρ [kg/m^3]	ρ_a[kg/m^3]	C[%]	p_t[%]
Ordinary concrete	2500	2200-2450	88-98	2-12
Autoclaved cellular concrete	2500	300-1200	12-48	52-88
Brick	2500	1000-1800	40-72	28-60
Deciduous wood	1500	800-1000	53-67	33-47
Resinous wood	1500	500-800	33-53	47-67
Steel	7850	7850	100	0
Glass	2600	2600	100	0
Mortars	2500	1500-1800	60-72	28-40

Apparent volume is compound of actual volume V and pores' volume:

$$V_a = \mathrm{V} + \mathrm{V}_{\mathrm{pores}} \;=>\; \mathrm{V_a} \geq V \;=>\; \mathrm{C} \leq 1$$

(C=1 for materials without pores)

Compactness influences the materials properties such as: mechanical resistance, permeability, frost resistance etc.

2.2. Porosity represents the unfilling grade with solid matter of an apparent volume of a material. In accordance with the pores' nature, there are two types of porosities: total one and apparent (open) one. p_t – total porosity is the ratio between total volume of closed and open pores (V_{pores}) and apparent volume of a material (V_a). So, it is the complement of the compactness C.

$$\%p_t=(V_{pores}/V_a)x100=[(V_a-V)/V_a]x100=100 - \%C$$

$$\%p_t =(\rho-\rho_a)/\rho=1- \rho_a/\rho$$

$$C+p_t=1$$

2.3. Water absorption represents the property of a material to absorb and keep water into its pores. It is determined experimentally by drying a sample at 105…110 Celsius degrees and than saturating it with water. We know the apparent volume V_a, saturated mass m_{sa} and dried mass m_{us} of a sample. Function of material's nature saturation process can be done: at usual pressure, at under pressure (20 ml col. Hg), at high pressure (15 N/mm2) by boiling. Saturated sample is weighed m_{ga}. Water absorption is obtained as ratio function at volume (a_v) or function of mass (a_m).

$$\%\mathrm{a}_v = \left[\frac{(m_{sa} - m_{us})}{V_a . \rho_w}\right] . 100 = \left[\frac{(m_{sa} - m_{su})}{m_{us}}\right]\left(\frac{\rho_a}{\rho_w}\right) . 100$$

$$\%\mathrm{a}_m = \left[\frac{(m_{sa} - m_{su})}{m_{us}}\right] . 100$$

where:

m_{us} : drying mass of sample
m_{sa} : saturated mass with of sample
V_a : apparent volume
ρ_w : water density
ρ_a : apparent density of sample

$$\%\mathrm{a}_v = \%\mathrm{a}_m\left(\frac{\rho_a}{\rho_w}\right) \ or \ \mathrm{a}_v = \mathrm{a}_m\left(\frac{\rho_a}{\rho_w}\right)$$

EXPERIMENT # 2: TENSILE TEST

Objectives

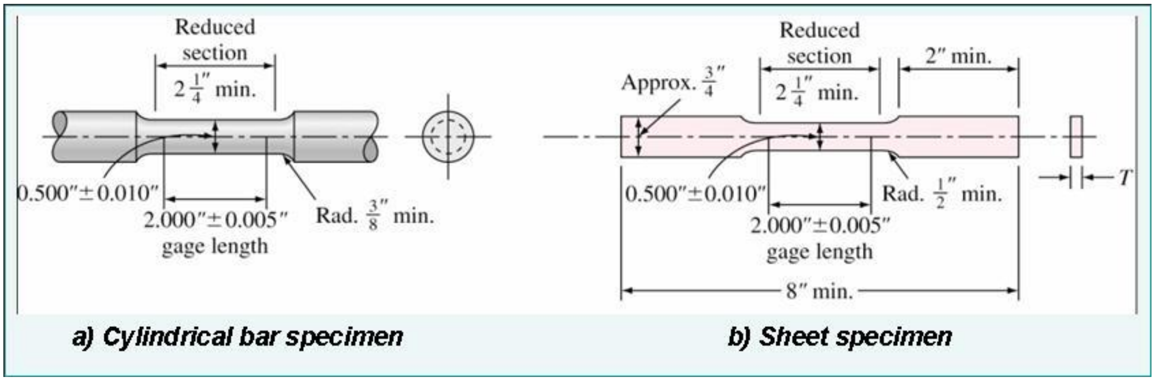
- Students are required to understand the principle of a uniaxial tensile testing and gain their practices on operating the tensile testing machine to achieve the required tensile properties.
- Students are able to explain load-extension and stress-strain relationships and represent them in graphical forms.
- To evaluate the values of ultimate tensile strength, yield strength, % elongation, fracture strain and Young's Modulus of the selected metals when subjected to uniaxial tensile loading.
- Students can explain deformation and fracture characteristics of different materials such as aluminium, steels or brass when subjected to uniaxial tensile loading.

1. Literature Review

1.1 Uniaxial tensile testing

- Uniaxial tensile test is known as a basic and universal engineering test to achieve material parameters such as ultimate strength, yield strength, % elongation, % area of reduction and Young's modulus. These important parameters obtained from the standard tensile testing are useful for the selection of engineering materials for any applications required.
- The tensile testing is carried out by applying longitudinal or axial load at a specific extension rate to a standard tensile specimen with known dimensions (gauge length and cross sectional area perpendicular to the load direction) till failure. The applied tensile load and extension are recorded during the test for the calculation of stress and strain. A range of universal standards provided by Professional societies such as American Society of Testing and Materials (ASTM), British standard, JIS standard and DIN standard provides testing are selected based on preferential uses. Each standard may contain a variety of test standards suitable for different materials, dimensions and fabrication history. For instance, ASTM E8: is a standard test method for tension testing of metallic materials and ASTM B557 is standard test methods of tension testing wronght and cast aluminum and magnesium alloy products
- A standard specimen is prepared in a round or a square section along the gauge length as shown below, depending on the standard used. Both ends of the specimens should have sufficient length and a surface condition such that they are firmly gripped during testing. The initial gauge length Lo is standardized (in several countries) and varies with the diameter (Do) or the cross-sectional area (Ao) of the specimen as listed in table 1. This is because if the gauge length is too long, the % elongation might be underestimated in this case. Any heat treatments should be applied on to the specimen prior to machining to produce the final specimen readily for testing. This has been done to prevent surface oxide scales that might act as stress concentration which might subsequently affect the final tensile properties due to premature failure. There might be some exceptions, for examples, surface hardening or surface coating on the materials. These processes should be employed

after specimen machining in order to obtain the tensile properties results which include the actual specimen surface conditions.



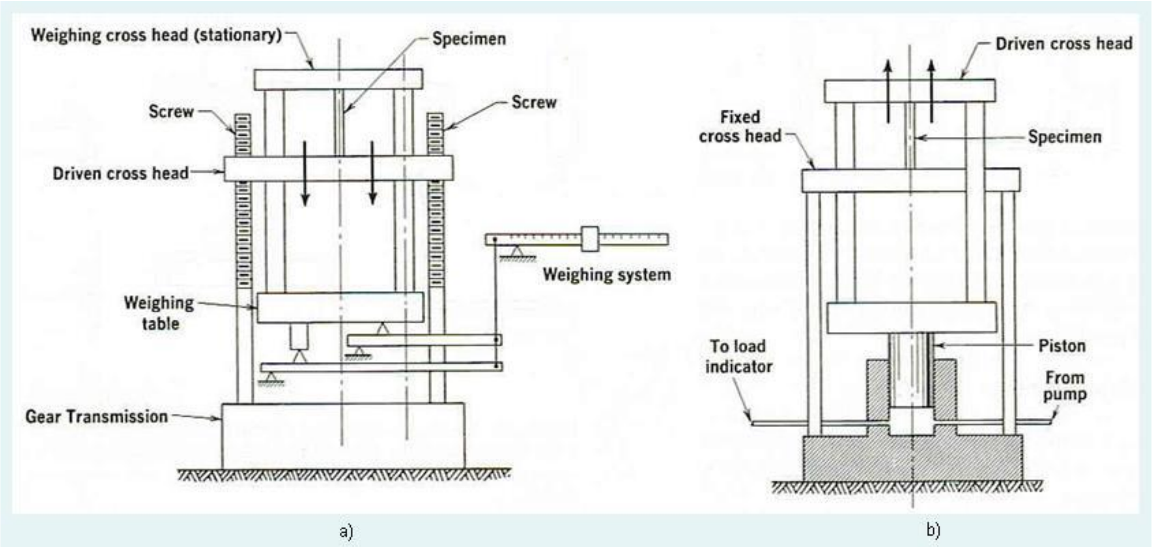
a) Cylindrical bar specimen

b) Sheet specimen

- Figure 1: Standard tensile specimens

– Type specimen	– United State (ASTM)
– Sheet ($L_0/\sqrt{A_0}$)	– 4,5
– Rod ($L_0/\sqrt{D_0}$)	– 4,0

- Table 1: Dimensional relationships of tensile specimens used in different countries.
- The equipment used for tensile testing ranges from simple devices to complicated controlled systems. The so-called universal testing machines are commonly used. These types of machines can be used not only for tension, but also for compression and cyclic (tension-compression). Most of the machines used nowadays are linked to a computer-controlled system in which the load and extension data can be graphically displayed together with the calculations of stress and strain.
- General techniques utilized for measuring loads and displacements employs sensors providing electrical signals. Load cells are used for measuring the load applied while strain gauges are used for strain measurement. A Change in a linear dimension is proportional to the change in electrical voltage of the strain gauge attached on to the specimen.



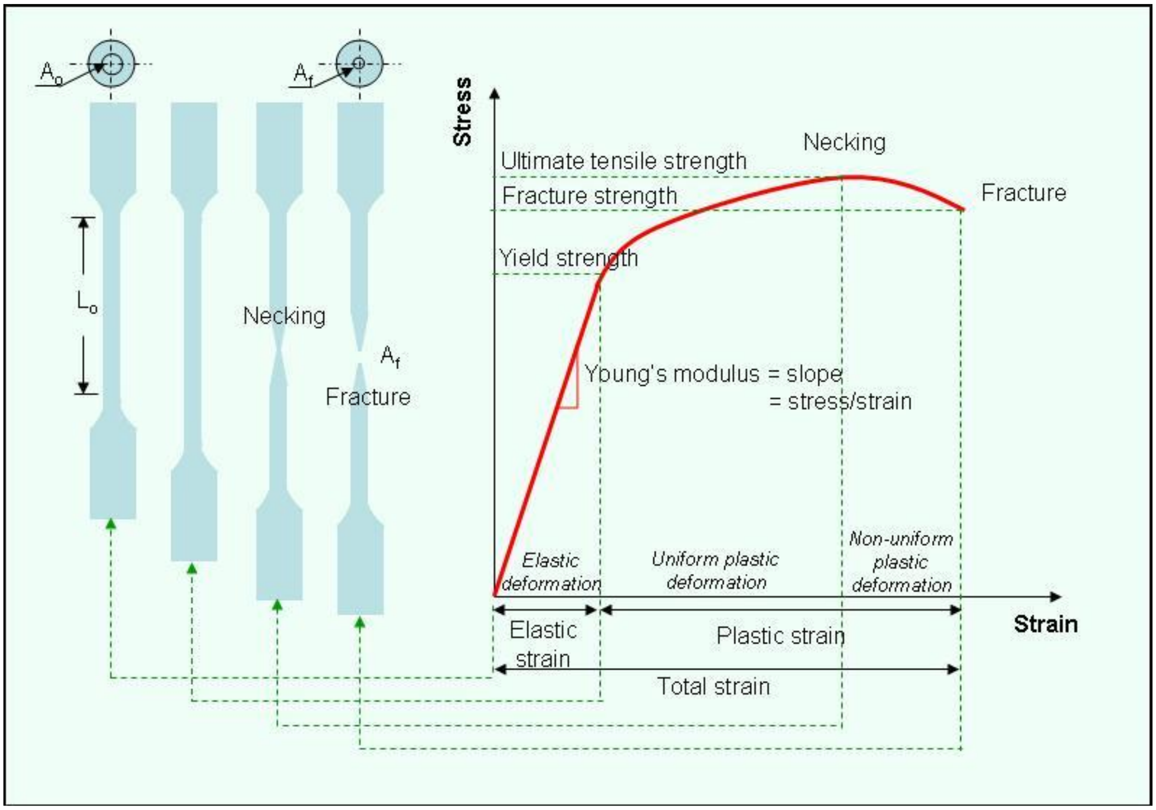
1.2 Stress and strain relationship

- When a specimen is subjected to an external tensile loading, the metal will undergo elastic and plastic deformation. Initially, the metal will elastically deform giving a linear relationship of load and extension. These two parameters are then used for the calculation of the engineering stress and engineering strain to give a relationship as illustrated in next figure using equations as follows.
- $\sigma = \frac{P}{A_0}$ $\qquad\qquad$ $\varepsilon = \frac{L_f - L_0}{L_0} = \frac{\Delta L}{L_0}$

where

σ	is the engineering stress
ε	is the engineering strain
P	is the external axial tensile load
A0	is the original cross-sectional area of the specimen
L0	is the original length of the specimen
Lf	is the final length of the specimen

The unit of the engineering stress is Pascal (Pa) or N/m2 according to the SI Metric Unit.



1.2.1 Young's modulus, E

During elastic deformation, the engineering stress-strain relationship follows the Hook's Law and the slope of the curve indicates the Young's modulus (E) $\qquad E = \frac{\sigma}{\varepsilon}$

Young's modulus is of importance where deflection of materials is critical for the required engineering applications. This is for examples: deflection in structural beams is considered to be crucial for the design in engineering components or structures such as bridges, building, ships, etc. The applications of tennis racket and golf club also require specific values of spring constants or Young's modulus values.

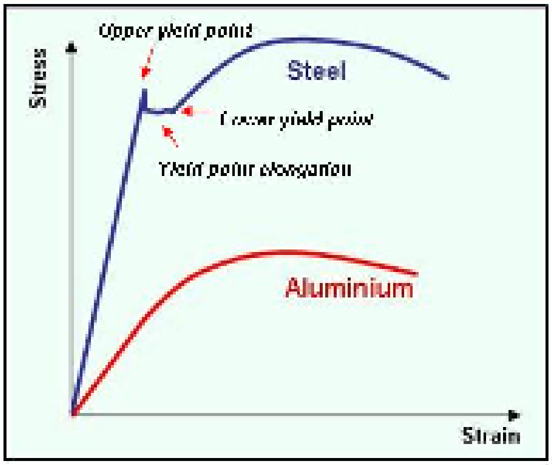
1.2.2 Yield strength, σy

By considering the stress-strain curve beyond the elastic portion, if the tensile loading continues, yielding occurs at the beginning of plastic deformation. The yield stress, σy, can be obtained by dividing the load at yielding (Py) by the original cross-sectional area of the specimen (A0)
as shown in equation 4.

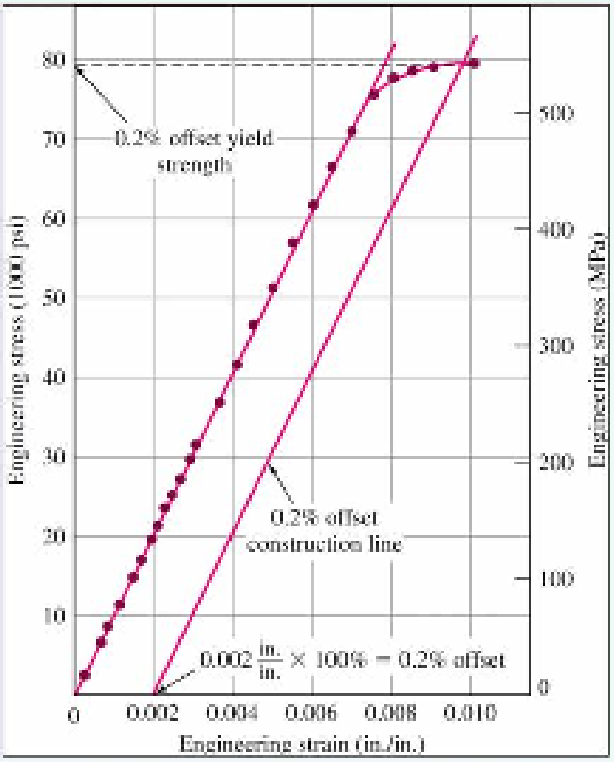
$$\sigma_y = \frac{P_y}{A_0}$$

The yield point can be observed directly from the load-extension curve of the BCC metals such as iron and steel or in polycrystalline titanium and molybdenum, and especially low carbon steels, see figure 3 a). The yield point elongation phenomenon shows the upper yield point followed by a sudden reduction in the stress or load till reaching the lower yield point. At the yield point elongation, the specimen continues to extend without a significant change in the stress level. Load increment is then followed with increasing strain. This yield point phenomenon is associated with a small amount of interstitial or substitutional atoms. This is for example in the case of low-carbon steels, which have small atoms of carbon and nitrogen present as impurities. When the dislocations are pinned by these solute atoms, the stress is raised in order to overcome the breakaway stress required for the pulling of dislocation line from the solute atoms. This dislocation pinning is related to the upper yield point as indicated in figure 4 a). If the dislocation line is free from the solute atoms, the stress required to move the dislocations then suddenly drops, which is associated with the lower yield point. Furthermore, it was found that the degree of the yield point effect is affected by the amounts of the solute atoms and is also influenced by the interaction energy between the solute atoms and the dislocations. Aluminum on the other hand having a FCC crystal structure does not show the definite yield point in comparison to those of the BCC structure materials, but shows a smooth engineering stress strain curve. The yield strength therefore has to be calculated from the load at 0.2% strain divided by the original cross-sectional area as follows

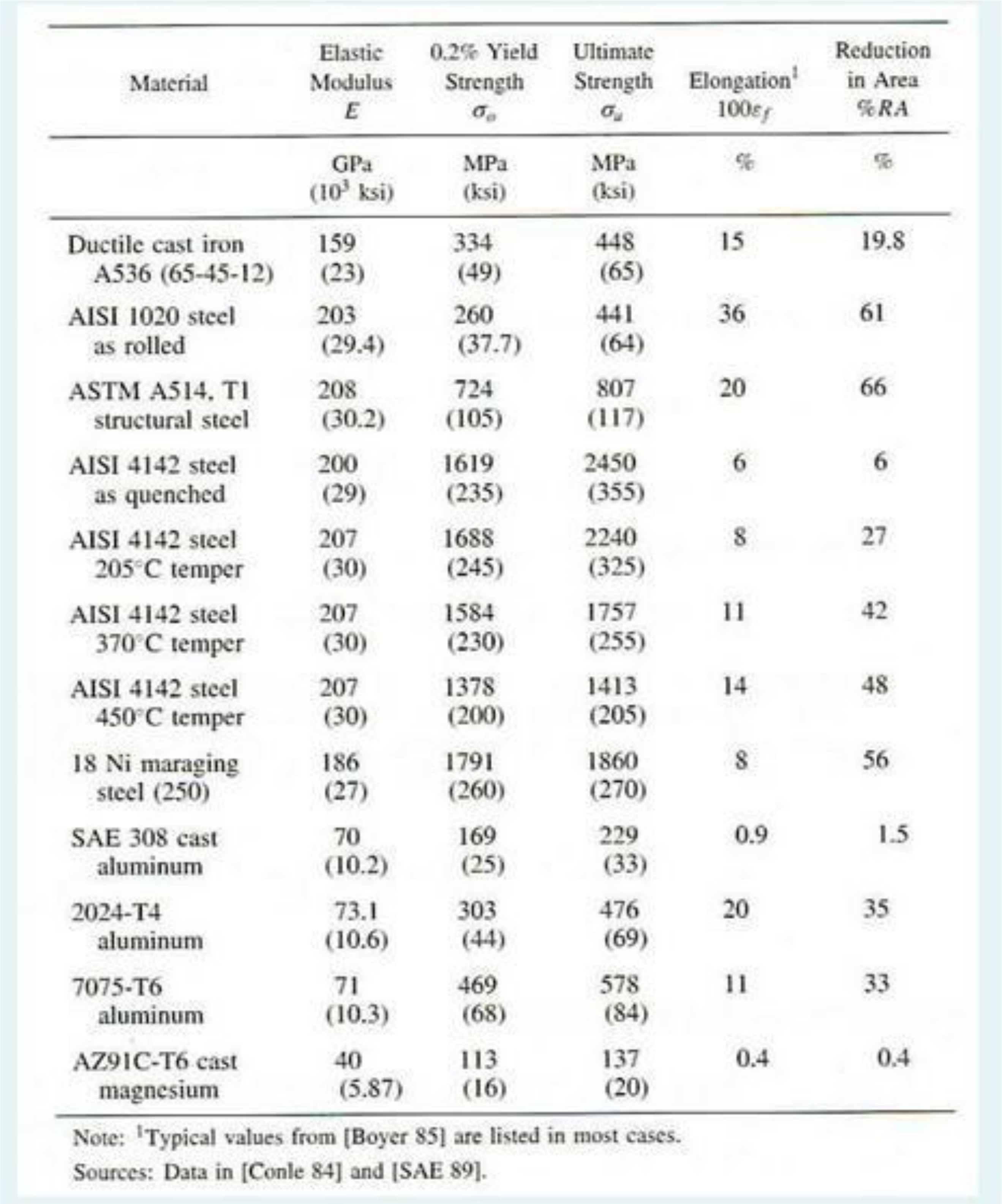
$$\sigma_{0,2\%y} = \frac{P_{y0,2\%}}{A_0}$$



a) Stress-strain curve of steel and aluminium.



b) Determination of the yield point at 0.2% offset.



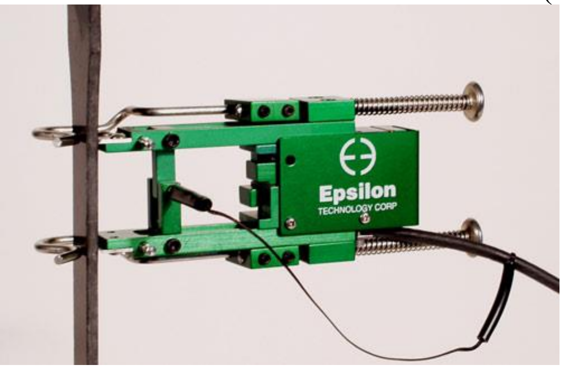
Material	Elastic Modulus E	0.2% Yield Strength σ_o	Ultimate Strength σ_u	Elongation[1] $100\varepsilon_f$	Reduction in Area $\%RA$
	GPa (10^3 ksi)	MPa (ksi)	MPa (ksi)	%	%
Ductile cast iron A536 (65-45-12)	159 (23)	334 (49)	448 (65)	15	19.8
AISI 1020 steel as rolled	203 (29.4)	260 (37.7)	441 (64)	36	61
ASTM A514, T1 structural steel	208 (30.2)	724 (105)	807 (117)	20	66
AISI 4142 steel as quenched	200 (29)	1619 (235)	2450 (355)	6	6
AISI 4142 steel 205°C temper	207 (30)	1688 (245)	2240 (325)	8	27
AISI 4142 steel 370°C temper	207 (30)	1584 (230)	1757 (255)	11	42
AISI 4142 steel 450°C temper	207 (30)	1378 (200)	1413 (205)	14	48
18 Ni maraging steel (250)	186 (27)	1791 (260)	1860 (270)	8	56
SAE 308 cast aluminum	70 (10.2)	169 (25)	229 (33)	0.9	1.5
2024-T4 aluminum	73.1 (10.6)	303 (44)	476 (69)	20	35
7075-T6 aluminum	71 (10.3)	469 (68)	578 (84)	11	33
AZ91C-T6 cast magnesium	40 (5.87)	113 (16)	137 (20)	0.4	0.4

Note: [1]Typical values from [Boyer 85] are listed in most cases.

Sources: Data in [Conle 84] and [SAE 89].

2. Materials and equipment

2.1 Universal testing machine (300kN)
2.2 Mechanical Extensometer (0,1μm) or Video Extensometer



2.3 calipers

3. Experimental procedure

Step1: The specimens provided are made of aluminum, steel. Measure and record specimen dimensions (diameter and gauge length) in a table provided for the calculation of the engineering stress and engineering strain. Marking the location of the gauge length along the parallel length of each specimen for subsequent observation of necking and strain measurement.
Step2: Fit the specimen on to the universal Testing Machine (UTM) and carry on testing. Record load and extension for the construction of stress-strain curve of each tested specimen.
Step3: Fit the mechanical extensometer on the specimen and connect it in ME machine port.
Step4: - Open the machine software
Open a new sheet
select “Chaouachi rond tensile” program.
Step5: Update the specimen data and start the test.
Step6: Save the test data
Step7: Calculate Young's modulus, yield strength, ultimate tensile strength, fracture strain, % elongation and % area of reduction of each specimen and record on the provided table.
Step8: Analyze the fracture surfaces of broken specimens using stereoscope, sketch and describe the results.
Step9: Discuss the experimental results and give conclusions.

4. Results

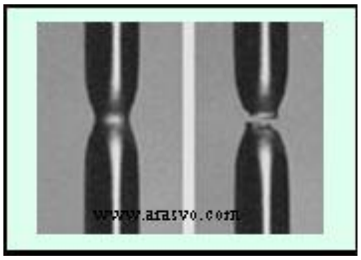
Details Materials	Aluminium	Steel	Brass
Diameter (mm)			
Width (mm)			
Thickness (mm)			
Cross-sectional area (mm2)			
Gauge length (mm)			
Young's modulus (GPa)			
Load at yield point (N)			
Yield strength (MPa)			
Maximum load (N)			
Ultimate tensile strength (MPa)			
% Elongation			
% Area of reduction			
Fracture strain			
Work hardening exponent (n)			
Fracture mode			
Fracture surfaces			
(Sketch)			

1.2.4 Fracture Strength, σf

After necking, plastic deformation is not uniform and the stress decreases ccordingly until fracture. The fracture strength (σ fracture) can be calculated from the load at fracture divided by the original cross-sectional area, Ao, as expressed in equation.

$$\sigma_{\mathrm{fracture}} = \frac{P_{\mathrm{fracture}}}{A_0}$$

1.2.5 Fracture Strain, εf



1.2.6 Tensile ductility

Tensile ductility of the specimen can be represented as % elongation or % reduction in area as expressed in the equations given below

$$\%\mathrm{Elongation} = \frac{\Delta L}{L_0} \mathrm{x}100$$

$$\%\mathrm{RA} = \frac{A_0 - A_f}{A_0} \mathrm{x}100 = \frac{\Delta A}{A_0} \mathrm{x}100$$

where Af is the cross-sectional area of specimen at fracture.

The fracture strain of the specimen can be obtained by drawing a straight line starting at the fracture point of the stress-strain curve parallel to the slope in the linear relation. The interception of the parallel line at the x axis indicates the fracture strain of the specimen being tested.

5. Describe the engineering stress-strain curve

EXPERIMENT # 3: IMPACT TEST

Scope

This test method covers the determination of Impact toughness (strain energy) through

Theory

In an impact test a specially prepared notched specimen is fractured by a single blow from a heavy hammer and energy required being a measure of resistance to impact.

Impact load is produced by a swinging of an impact weight W (hammer) from a height h. Release of the weight from the height h swings the weight through the arc of a circle, which strikes the specimen to fracture at the notch (figure below)

Kinetic energy of the hammer at the time of impact is mv2/2, which is equal to the relative potential energy of the hammer before its release. (mgh), where m is the mass of the hammer and $v = \sqrt{(2gh)}$ is its tangential velocity at impact, g is gravitational acceleration (9.806 m/s 2) and h is the height through which hammer falls. Impact velocity will be 5.126 m/s or slightly less.

Here it is interesting to note that height through which hammer drops determines the velocity and height and mass of a hammer combined determine the energy.

Energy used can be measured from the scale given. The difference between potential energies is the fracture energy. In test machine this value indicated by the pointer on the scale. If the scale is calibrated in energy units, marks on the scale should be drawn keeping in view angle of fall () and angle of rise Height h1 and h2 equals,

$h1= R (1-\cos\alpha)$ and $h2= (1-\cos\beta)$

With the increase or decrease in values, gap between marks on scale showing energy also increase or decrease. This can be seen from the attached scale with any impact machine.

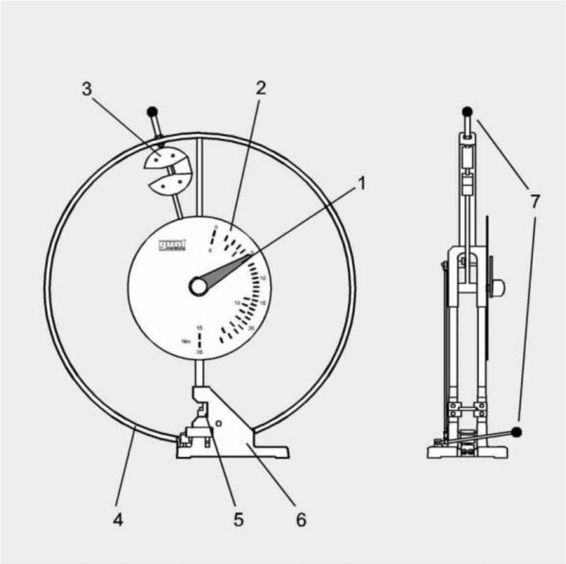
Energy used in fracturing the specimen can be obtained approximately as

Wh1-Wh2

This energy value called impact toughness or impact value, which will be measured, per unit area at the notch.

Test Specimen and Equipment:

Impact testing machine WP400 . (Fig. below)



1 trailing pointer,

2 measuring scale,

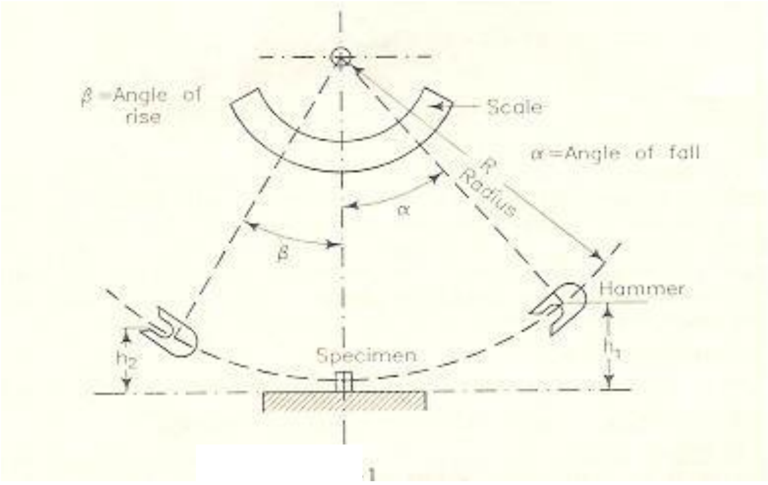
3 hammer with removable additional weights,

4 guard ring,

5 specimen holder wit specimen,

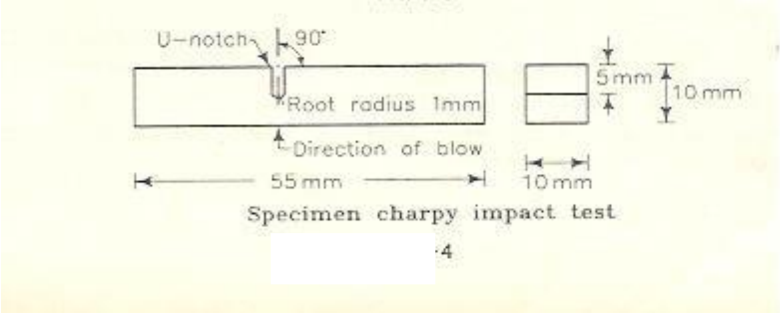
6 unit base,

7 two hand trigger and brake

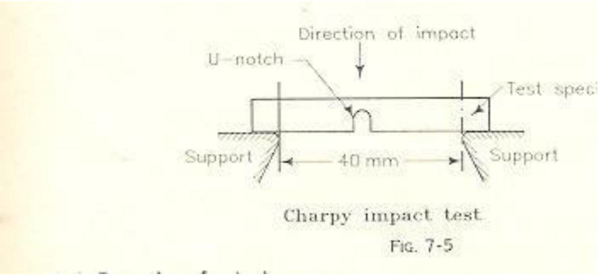


Schematic impact testing

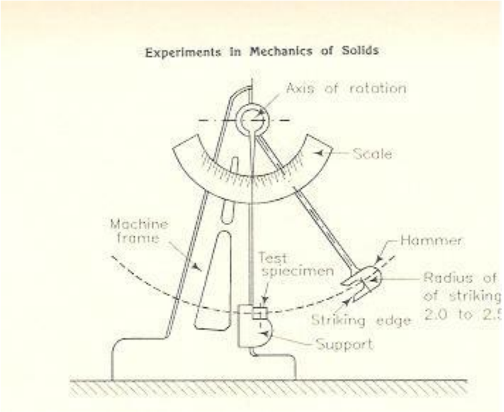
2. U notch is cut across the middle of one face as shown in (fig. below).



Specimen for Charpy test



Charpy impact testing equipment



Mounting of specimen

Specimen is tested as a beam supported at each end (fig. below). Hammer is allowed to hit then specimen at the opposite face behind the notch.

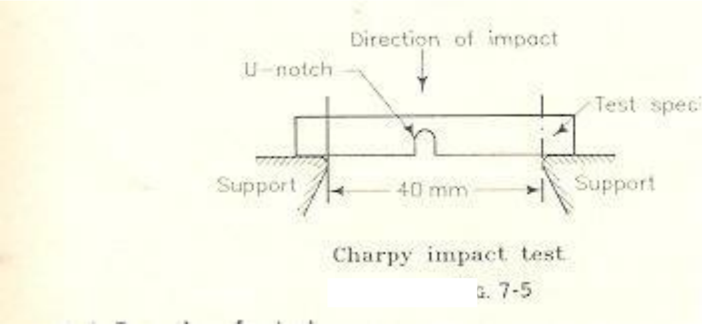


Figure Mounting of specimen.

Procedure

Step1: Measure the dimensions of a specimen. Also, measure the dimensions of the notch.
Step2: Raise the hammer and note down initial reading from the dial, which will be energy to be used to fracture the specimen.
Step3: Place the specimen for test and see that it is placed center with respect to hammer. Check the position of notch.
Step4: Release the hammer and note the final reading. Difference between the initial and final reading will give the actual energy required to fracture the Specimen.
Step5: Repeat the test for specimens of other materials.
Step6: Compute the energy of rupture of each specimen.

Observation

Initial and final reading of the dial.

Result Strain energy of given specimen is …………….

EXPERIMENT # 4: TORSION TESTING

1-Objectives

1) Students are required to understand the principles of torsion testing, practice their testing skills and interpreting the experimental results of the provided materials when failed under torsion.

2) To determine the maximum shearing stress of the tested materials.

3) Students are able to differentiate the ability of materials such as cast iron and brass to withstand torque prior to torsion failure. Analysis and interpretation of the test parameters obtained should be carried out in relation to the failure nature of each material.

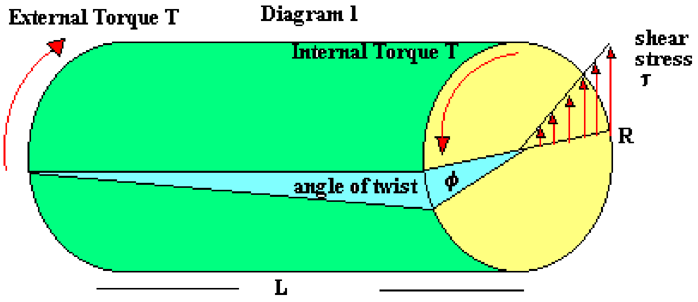
4) Students are capable of selecting materials for engineering applications associated with torsion.

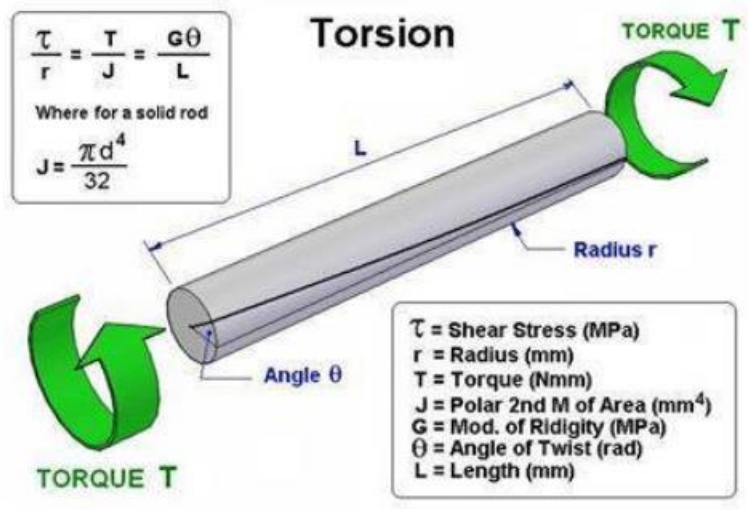
2-Literature review

In many areas of engineering applications, materials are sometimes subjected to torsion in services, for example, drive shafts, axles and twisted drills. Moreover, structural applications such as bridges, springs, car bodies, airplane fuselages and boat hulls are randomly subjected to torsion. The materials used in this case should require not only adequate strength but also be able to withstand torque in operation. Even though torsion test is not as universal as tension test and do not have any standardized testing procedure, the significance lies on particular engineering applications and for the study of plastic flow in materials. Torsion test is applicable for testing brittle materials such as tool steels and the test has also been used to determine the forge ability of the materials by means of torsion testing at elevated temperatures.

3- Theory

Considering a cylindrical bar with one end being twisted, the twisting moment MT is resisted by the shear stress τ existing across the specimen section. This shear stress is zero at the center of the bar, increases linearly with its radius and finally reaches its maximum value at the peripheral of the bar. If the cylindrical bar with a length of L, the twisting moment can be related to the shear stress as follow





Within the elastic range of deformation, the shear stress can be calculated according to (equation 1)

$$\tau = \frac{M_T . r}{J}$$

For a solid cylindrical specimen, the polar moment (equation 2)

$$J = \frac{\pi . D^4}{32}$$

we can therefore determine the shear stress as shown (equation 3)

$$\tau = \frac{16 M_T}{\pi . D^3}$$

For a tube specimen, the maximum shear stress at the peripheral of the tube can be calculated from (equation 4)

$$\tau = \frac{16 M_T . D_1}{\pi . \left({D_1}^4 - {D_2}^4 \right)}$$

where D_1 : is the outer diameter of the tube
D_2 : is the inner diameter of the tube

4- **Equipment**

- caliber
- NJS-30 Torsion Testing Machine

5- Experimental Procedure

1- Measure initial diameter, initial length and initial gauge length of the specimen. Record these parameters on the table provided.

2 Draw a line using a permanent pen along the length of the test specimen. This line will help to notice the degree of rotation during applying the twisting moment.

3 Preparation before the test

Get the power connected, preheat about 30 minutes; Press Force Clear to reset testing force at zero.

Specimen Test

Step 1: In system waiting status, turning the handle to adjust the grips, and installs the Specimen properly according to requirement.

Step 2: in the system waiting status, press Function to set the trial date, Gauge length, diameter, wall thickness according to status prompting area.

Step 3: press Test to start the test, when the torque reaches torque value T_0, the twist angle automatically cleared and begins to reverse the trial. Twist the hand-wheel to choose whether to break the specimen or not; if yes, when specimen is broken, the trial will be end automatically; if not, press Stop to end the testing.

Step 4: the screen displays the testing data processing window, displays the maximum torque, maximum torsion angle, torsion strength, diameter, wall thickness, gauge length, Item No..

Step 5: According to promoting info, press Function to save the test, and press Exit to quit the test; press Query to check the testing result, then press ▲ for former group test data, while press ▼ for the next group test data; Data query can also be available by entering the corresponding group number; if the input numbers exceed its group number, then it will show null; press Clear or re-enter the correct number of groups to continue the query; in query status, enter the needed group number, then press Clear to print the test data.

Note: This machine can only store 40 groups of testing data; when memory is filled with 40 groups, press Function save one more, the test data processing window will prompts that the data is full, please clear first and then save! Then you need to press Exit to return to the system waiting status; Press Clear, the system status display area prompts that whether to continue data cleaning? Press Confirm, all the stored data will be cleared. If the data stored less than 40 sets, pressing the clear key will also remove all previous saved data, and restart testing from 00 groups. 4 Grip the test specimen on to the torsion testing machine using hexagonal sockets and make sure the specimens are firmly mounted. Fit both ends of the specimen to input and torque shafts and set reading on the torque meter to zero.

5 Start twisting the specimen at strain increment of 0.5o until failure occurs. Record the received data rotation in the table provided for the construction of torque and degree relationship

6 Construct the relationship between shear stress and shear strain. Determine maximum shear stress, shear stress at proportional limit and modulus of rigidity.

7 Sketch fracture surfaces of failed specimens and described their natures in the table provided.

8 Discuss and conclude the obtained experimental results.

6. Notes & Remarks:

1 Please check the accuracy of the variety of connections, and also the correct power supply; make sure the power is AC 220V, with good earthing.

2 Please confirm the test parameters set up correctly to ensure the accuracy of test data.

EXPERIMENT # 5: Sieve Analysis

ASTM Standards: ASTM C 136 – 06

Scope

This test method covers the determination of granular materials using sieves with square openings.

Summary of Test Method

A sample of dry aggregate of known mass is separated through a series of sieves of progressively smaller openings for determination of particle size distribution.

Significance and Use

a) This test method is used primarily to determine the grading of materials proposed for use as aggregates or being used as aggregates. The results are used to determine compliance of the particle size distribution with applicable specification requirements and to provide necessary data for control of the production of various aggregate products and mixtures containing aggregates. The data may also be useful in developing relationships concerning porosity and packing.

b) Accurate determination of material finer than the 75-µm (No. 200) sieve cannot be achieved by use of this test method alone. Test Method C 117 for material finer than 75-µm sieve by washing should be employed.

c) Refer to methods of sampling and testing in Specification C 637 for heavyweight aggregates.

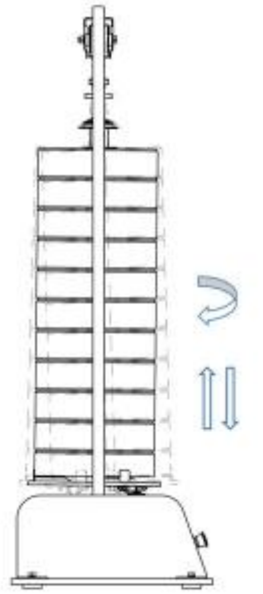
Apparatus

a) Balances used in testing fine and coarse aggregate shall have readability and accuracy as follows:

- For fine aggregate: 0.1 g or 0.1 % of the test load.
- For coarse aggregate: 0.5 g or 0.1 % of the test load.

b) Sieves Standard 200 or 300mm (8" or 12") round sieves with square openings (3/2”, 1”, ¾”, ½”, 3/8”, N4, N8, N16, N30, N50, N100, N200)

c) Mechanical Sieve Shaker: the mechanical sieve shaker is recommended



d) Oven of appropriate size capable of maintaining a uniform temperature of 110 ± 5 °C.

e) Miscellaneous: Necessary bowls, pans, spatulas etc.;

6. Procedure &Sampling

Step 1 Place in an oven at 110 ± 5 °C and dry to a constant weight.

Step 2 When sample is dry remove from oven, cool to room temperature, weigh pan & sample to the nearest 0.1 gram and record on work sheet.

Step 3 Pour entire sample into a nested set of 200 or 300mm (8" or 12") round sieves. (Use sieve sizes required by specifications for the type of material being tested.)

Step 4 Place the sieve nest in the shaker and sieve until no more than 0.5% by weight of total sample passes any individual sieve during one minute of shaking (more than approximately 10 min) to achieve adequate sieving may result in degradation of the sample.

Step 5 After sieving has been completed, remove each sieve from top to bottom, weigh and record the material retained on each sieve (to the nearest 0.1 gram) on the work sheet under the correct sieve size. Also, weigh and record the material in the bottom pan and the pan weight (both to the nearest 0.1 gram). After all weights have been recorded, add all the weights, the total weight must check with the original weight within ±0.3%. If not the sample shall be re-sieved and each individual sieve re-weighed. In no case; however, shall the fraction retained on any sieve at the completion of the sieving operation weigh more than 200 grams (200mm [8"] sieves) or 450 grams (300mm [12"] sieves). This can be regulated by the introduction of a sieve having a larger opening placed above the critical sieve.

− **Do not** : use a sharp object to remove particles stuck in the mesh. This can result in oversize openings making the sieve unacceptable.

Calculations

$$\%\ \text{Passing} = \frac{\text{Total Weight of Material Passing a Particular Sieve}}{\text{Total of Weights Retained on All Sieves Plus Bottom Pan Plus Loss by Washing}} \text{ x } 100$$

Report

a) Depending upon the form of the specifications for use of the material under test, the report shall include the following:

1) Total percentage of material passing each sieve, or
2) Total percentage of material retained on each sieve, or
3) Percentage of material retained between consecutive sieves.

b) Report percentages to the nearest whole number, except if the percentage passing the 75-µm (No. 200) sieve is less than 10 %, it shall be reported to the nearest 0.1 %.

c) Report the fineness modulus, when required, to the nearest 0.01 Sample the aggregate in accordance with Practice D 75.

SIEVE ANALYSIS TEST REPORT

Project Name: ··.

Report Date : ···.

By: ···.

Location: ··..···············.

Sampled Location: ···.

Sample Date: ···.

TESTING INFORMATION

Sample weight: ····································· (g)

Total loss after sieving, <0.3%: ····················· (%)

Sieve size	Weight Retained (g)	Cumulative Weight Retained (g)	% Retained Each Sieve	% Passing
2.5" (63.5 mm)				
2" (50 mm)				
1.5" (37.5 mm)				
1" (25 mm)				
0.75" (19 mm)				
0.5" (12.5 mm)				
0.375" (9.5 mm)				
No.4 (4.75 mm)				
No.8 (2.36 mm)				
No.16 (1.18 mm)				
No.30 (600 μm)				
No.50 (300 μm)				
No.100 (150 μm)				
No.200 (75 μm)				

REMARKS:

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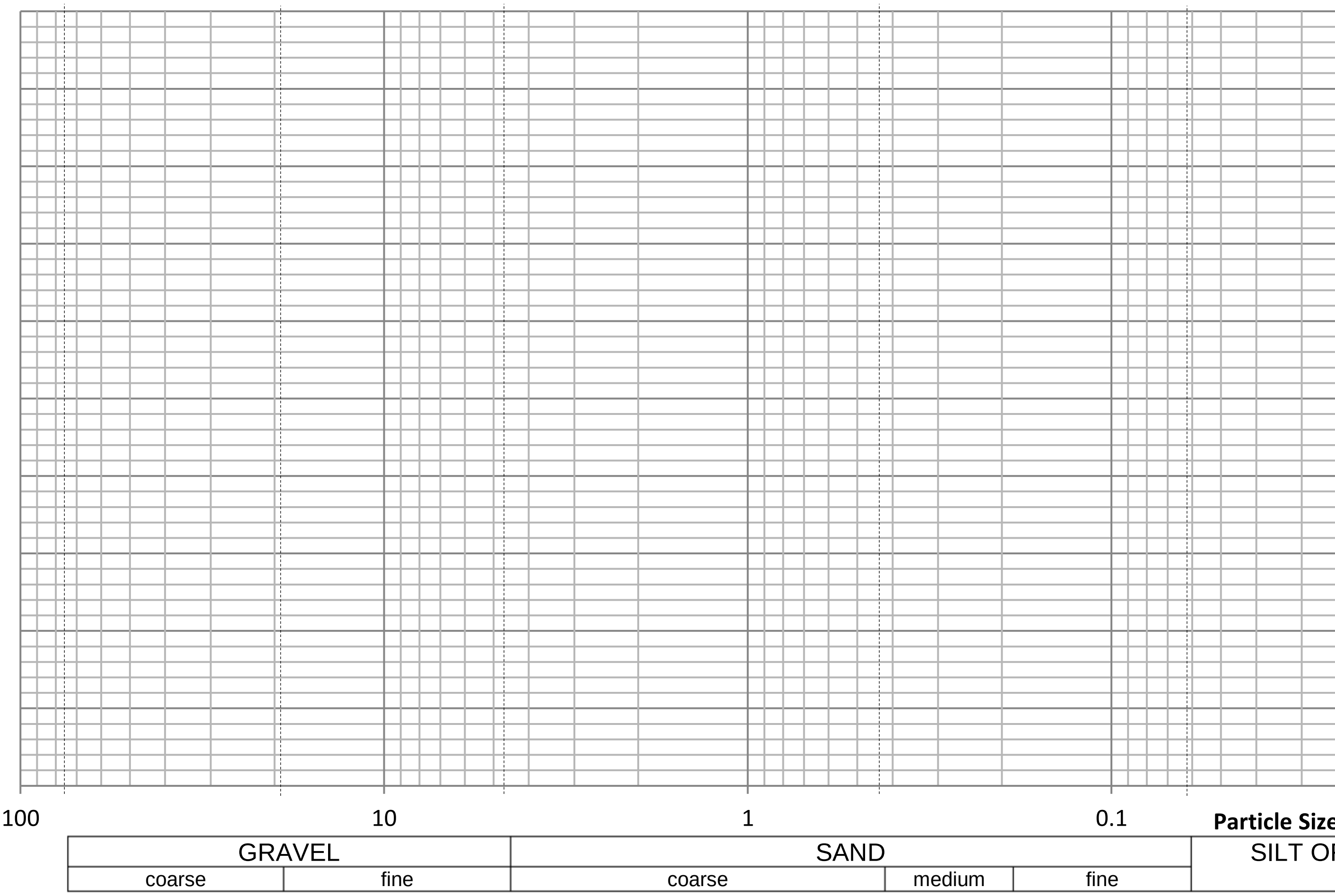
···..

Sieve Analysis (Curve for aggregate)



EXPERIMENT # 5: LOS ANGELES RATTLER

AASHTO Designation T 96

Refer to ASTM Designation C131 or C535

Scope

This method covers the procedure for testing crushed rock, slag and gravel and uncrushed gravel for resistance to abrasion using the Los Angeles testing machine.

Summary of Method

The Los Angeles Rattler test is a measure of degradation of mineral aggregates of standard grading resulting from a combination of actions including abrasion or attrition, impact, and grinding in a rotating steel drum containing a specified number of steel spheres (dependent upon the test sample's grading). As the drum rotates, a shelf plate picks up the sample and the steel spheres, carrying them around until they are dropped to the opposite side of the drum, causing an impact-crushing effect. The contents then roll within the drum with an abrading and grinding action until the shelf plate impacts and the cycle is repeated. After the prescribed number of revolutions, the contents are removed from the drum and the aggregate portion is sieved to measure the degradation as percent loss.

Apparatus

Los Angeles Abrasion Machine - See AASHTO T 96 specifications.

Sieves - Standard, a 4.75mm (#4) and a 1.70mm (#12) sieves conforming to the requirements of AASHTO M 92.

Balance - Conforming to the requirements of AASHTO Designation M 231 (Class G5 or better) with readability and sensitivity of 1 gram and an accuracy of 1 gram or 0.1%.

Oven - For drying samples capable of maintaining a temperature of 110 ± 5 °C

Charge - Shall consist of steel spheres averaging approx. 46.8mm (1 27/32") in diameter and each weighing between 390 and 445g.

Test Sample

The test sample shall be selected from washed aggregate, dried to a constant weight at 110 ± 5 °C. The tests samples shall be separated into individual size fractions and recombined to the grading shown in Table 1 below, most nearly corresponding to the range of sizes in the aggregate furnished for the work. The weight of the sample prior to the test shall be recorded to the nearest 1g.

TABLE 1 - Grading of Test Samples

Sieve sise (mm,in.)		Weight & Grading of test sample, (g)						
Passing	Retained on	A	B	C	D	E	F	G
75 (3)	63 (2 ½)					2500±50		
63 (2 ½)	50 (2)					2500±50		
50 (2)	37,5 (1 ½)					5000±50	5000±50	
37,5 (1 ½)	25 (1)	1250±25					5000±25	5000±25
25 (1)	19 (3/4)	1250±25						5000±25
19 (3/4)	12,5 (1/2)	1250±10	2500±10					
12,5 (1/2)	9,5 (3/8)	1250±10	2500±10					
9,5 (3/8)	6,3 (1/4)			2500±10				
6,3 (1/4)	4,75 (#4)			2500±10				
4,75 (#4)	2,36 (#8)				5000±10			
TOTAL		5000±10	5000±10	5000±10	5000±10	10000±100	10000±100	10000±100

Abrasive Charge & Revolutions

The abrasive charge, depending upon the grading of the test sample as described in a above Section, shall be in accordance with Table 2 below. The number of revolutions shall also conform to Table 2.

TABLE 2 - Charge & Revolutions

GRADING	NUMBER of SPHERES	WEIGHT of CHARGE (g)	NUMBER of REVOLUTIONS
A	12	5000 ± 25	500
B	11	4584 ± 25	500
C	8	3330 ± 20	500
D	6	2500 ± 15	500
E	12	5000 ± 25	1000
F	12	5000 ± 25	1000
G	12	5000 ± 25	1000

Procedure

Step1: Place the test sample and the abrasive charge in the Los Angeles testing machine and rotate the machine at a speed of 30 to 33 rpm for the prescribed number as shown in Table 2 above. A revolution counter with an automatic shutoff attached to the machine is an appropriate way to control the revolutions.

Step2: After the prescribed number of revolutions the material shall be discharged from the machine and a preliminary separation of the sample made on a 4.75mm (#4) sieve. Sieve the finer portion on a 1.70mm (#12) sieve. Wash the material coarser than the 1.70mm (#12) sieve, oven-dry to a constant weight at 110 ± 5 °C, and weigh to the nearest gram.

Calculation & Report

Express the loss (difference between the original weight and the final weight of the test sample) as a percentage of the original weight of the test sample.

The calculation is as follows where:

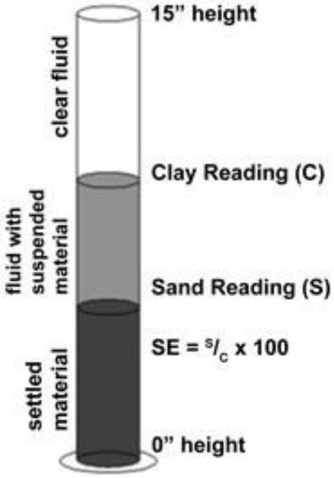
$$\%\text{Loss} = \frac{\text{Portion passing in the 1.70mm (\#12)sieve(g)}}{\text{The weight of the sample before testing (g)}}\text{x}100$$

EXPERIMENT # 7: SAND EQUIVALENT VALUE OF SOILS AND FINE AGGREGATE

(ASTM D 2419-79)

Scope:

This test method is intended to serve as a rapid field-correlation test. The purpose of this test method is to indicate, under standard conditions, the relative proportions of clay-like or plastic fines and dusts in granular soils and fine aggregates that pass the No. 4 sieve.



Apparatus Required:

- A graduated transparent acrylic plastic cylinder, rubber stopper, irrigator tube, weighted foot assembly and siphon assembly all conforming to the respective specifications.
- *Measuring Tin* - A tinned box approximately 2 1/4 in. in diameter having a capacity of 85 ± 5 ml.
- *No. 4 Sieve,* conforming to the requirements of Specifications E 11.
- *Funnel,* wide-mouth, for transferring test specimens into the graduated cylinder.
- *Bottles,* two 1-gal (3.78-L), to store stock solution and working solution.
- *Flat Pan,* for mixing.

- *Clock or Watch,* reading in minutes, and seconds.

- *Mechanical Sand Equivalent Shaker,* having a throw of 8 ± 0.04 in. and operating at 175 ± 2 cpm.

Reagents and Materials:

- *Stock Solution* - The materials listed below shall be required to prepare this solution.
- *Anhydrous Calcium Chloride,* 454 g of technical grade.
- *USP Glycerin,* 2050 g.
- *Formaldehyde,* (40 volume % solution) 47 g.
- *Working Calcium Chloride Solution* - Prepare the working calcium chloride solution as per the procedure outlined.

Sample Preparation:

- Obtain at least 1500 g of material passing the No. 4 sieve.
- Remove any coatings of fines adhering to the coarse aggregate.
- Prepare test specimens from the material passing the No. 4 sieve portion of the sample by the procedure given below:
- Split or quarter enough material to fill four tin measures to the brim or slightly rounded above the brim in the following manner:
- If it appears necessary, dampen the material to avoid segregation or loss of fines during the splitting or quartering operations
- Using the measuring tin, dip out four of these measures from the sample.
- Determine and record the amount of material contained in these four measures either by weight or by volume in a dry plastic cylinder.
- Return this material back to the sample and proceed to split or quarter the material making the necessary adjustments to obtain this predetermined weight or volume.
- Dry each test specimen to constant weight at 230 ± 9°F (105 ± 5°C) and cool to room temperature before testing.

Procedure:

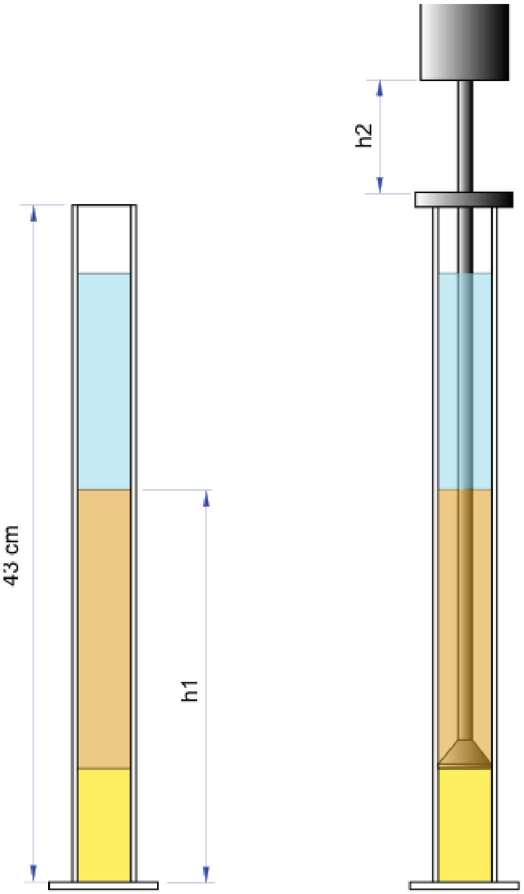
- Siphon 4 ± 0.1 in. of working calcium chloride solution into the plastic cylinder.
- Pour one of the test specimens into the plastic cylinder using the funnel to avoid spillage.
- Tap the bottom of the cylinder sharply on the heel of the hand several times to release air bubbles and to promote thorough wetting of the specimen.
- Allow the wetted specimen and cylinder to stand undisturbed for 10 ± 1 min.
- At the end of the 10-min soaking period, stopper the cylinder; then loosen the material from the bottom by partially inverting the cylinder and shaking it simultaneously.
- After loosening the material from the bottom of the cylinder, shake the cylinder and contents by mechanical shaker.
- Place the stoppered cylinder in the mechanical sand equivalent shaker, set the time, and allow the machine to shake the cylinder and the contents for 45 ± 1 seconds.
- *Irrigation Procedure* - During the irrigation procedure, keep the cylinder vertical and the base in contact with the work surface. Insert the irrigator tube in the top of the cylinder, remove the spring clamp from the hose, and rinse the material from the cylinder walls as the irrigator is lowered. Force the irrigator through the material to the bottom of the cylinder by applying a gentle stabbing and twisting action while the working solution flows from the irrigator tip. This flushes the material into suspension above the coarser sand particles.
- Regulate the flow just before the irrigator tube is entirely withdrawn and adjust the final level to the 15-in. graduation.
- Allow the cylinder and contents to stand undisturbed for 20 min ± 15 s. Start the timing immediately after withdrawing the irrigator tube.
- At the end of the 20-min sedimentation period read and record the level of the top of the clay suspension. This is referred to as the “clay reading.”
- After the clay reading has been taken, place the weighted foot assembly over the cylinder and gently lower the assembly until it comes to rest on the sand.
- As the weighted foot comes to rest on the sand, tip the assembly toward the graduations on the cylinder until the indicator touches the inside of the cylinder.
- Subtract 10 in. from the level indicated by the extreme top edge of the indicator and record this value as the “sand reading”.

Experimental Data and Results:

Tabulate the data in the given *‘Test Data Sheet’*

Calculation and Report:

- Calculate the sand equivalent to the nearest 0.1% as follows:



SE = (sand reading/clay reading) x 100
where:

SE = sand equivalent

- If the calculated sand equivalent is not a whole number, report it as the next higher whole number.
- Determine the average sand equivalent.

Discussion:

Discuss the following about the test in the given *'Test Data Sheet'*

- wetting of specimen
- irrigation
- clay and sand reading

SAND EQUIVALENT VALUE OF SOILS AND FINE AGGREGATES

Sample No. _______________Description of Material: _____________________________________

Tested by: ____________________________ Date of Testing: ______________________________

Original Weight of Sample, g: __________

Test No.	Clay Reading, C_r (inches)	Sand Reading, S_r (inches)	Sand Equivalent (S_r / C_r) x 100
1			
2			
3			
Average Sand Equivalent (SE)			

Discussion of Test Results: ____

____

____

____

EXPERIMENT # 8: TEST FOR FINENESS OF PORTLAND CEMENT BY AIR PERMEABILITY APPARATUS

Standard ASTM C204

1. Scope

This standard covers the procedure for determining by Blaine air permeability apparatus, the fineness of cement as represented by specific surface expressed as total surface area in cm2/g.

2. Principle

The rate of air flow through a sample is related to the pore size distribution which is related to the particle size distribution.

3. Apparatus

3.1 Blaine air-permeability apparatus

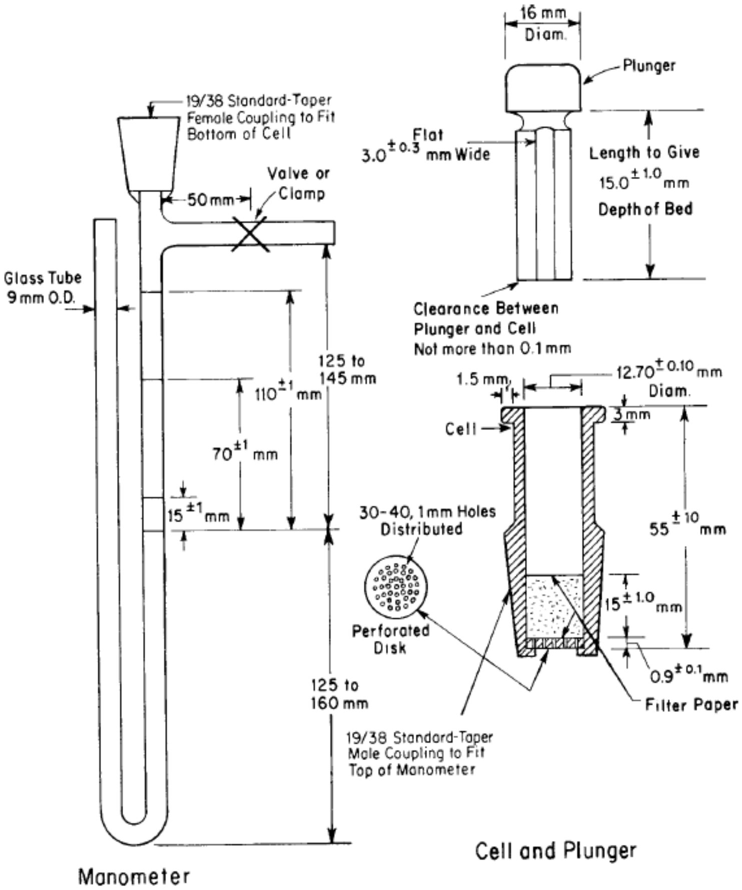


FIG. 1 Blaine Air-Permeability Apparatus

3.2 Balance: resolution ±0,001g

3.3 Timer

3.4 Place a filter paper disk

4. Procedures:

4.1 Preparation of Sample: Enclose the contents of a vial of the standard cement sample in a jar, approximately 120 cm3, and shake vigorously for 2 min to fluff the cement and break up lumps or agglomerates. Allow the jar to stand unopened for a further 2 min, then remove the lid and stir gently to distribute throughout the sample the fine fraction that has settled on the surface after fluffing.

4.2 Mass of Sample: The mass of the standard sample used for the calibration test shall be that required to produce a bed of cement having a porosity of 0.500 ± 0.005, and shall be calculated as follows:

$$W = \rho . V(1 - e)$$

where:

W = grams of sample required,
ρ = density of test sample (for Portland cement a value of 3.15 g/cm3 shall be used),
V = bulk volume of bed of cement, cm3, as determined in accordance with 4.2 (ASTM Standard C204)
e = desired porosity of bed of cement (0.500 ± 0.005)

4.3 Preparation of Bed of Cement: Seat the perforated disk on the ledge in the permeability cell, inscribed or marked face down. Place a filter paper disk on the metal disk and press the edges down with a rod having a diameter slightly smaller than that of the cell. Measure the mass to the nearest 0.001 g the quantity of cement and place in the cell. Tap the side of the cell lightly in order to level the bed of cement. Place a filter paper disk on top of the cement and compress the cement with the plunger until the plunger collar is in contact with the top of the cell. Slowly withdraw the plunger a short distance, rotate about 90°, repress, and then slowly withdraw. Use of fresh paper filter disks is required for each determination.

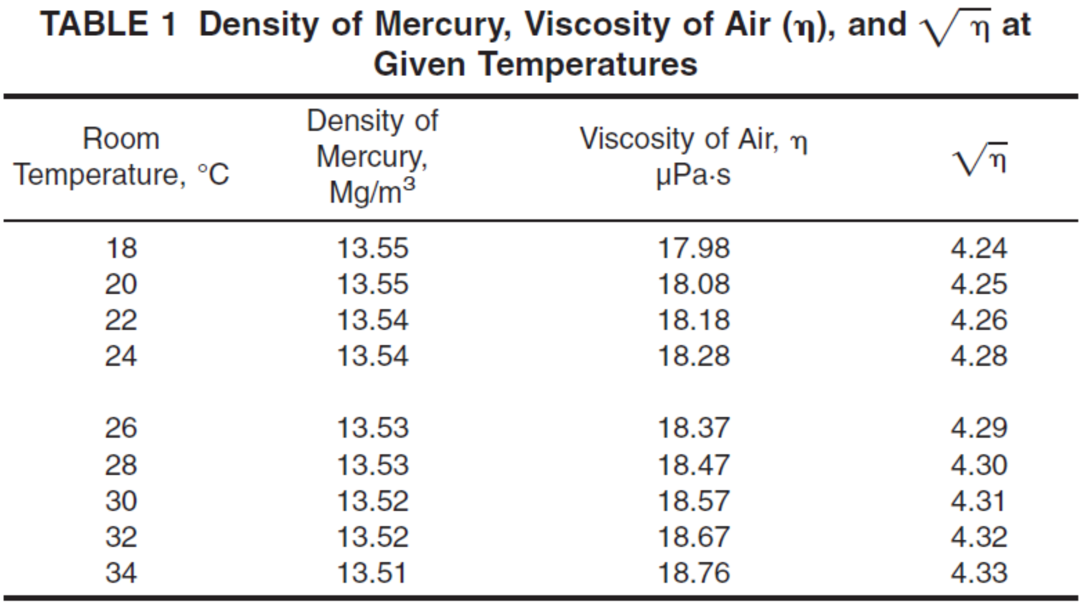


TABLE 1 Density of Mercury, Viscosity of Air (η), and $\sqrt{\eta}$ at Given Temperatures

Room Temperature, °C	Density of Mercury, Mg/m^3	Viscosity of Air, η µPa·s	$\sqrt{\eta}$
18	13.55	17.98	4.24
20	13.55	18.08	4.25
22	13.54	18.18	4.26
24	13.54	18.28	4.28
26	13.53	18.37	4.29
28	13.53	18.47	4.30
30	13.52	18.57	4.31
32	13.52	18.67	4.32
34	13.51	18.76	4.33

4.4 Permeability Test:

Step.1: Attach the permeability cell to the manometer tube, making certain that an airtight connection is obtained and taking care not to jar or disturb the prepared bed of cement.

Step.2: Slowly evacuate the air in the one arm of the manometer U-tube until the liquid reaches the top mark, and then close the valve tightly. Start the timer when the bottom of the meniscus of the manometer liquid reaches the second (next to the top) mark and stop when the bottom of the meniscus of liquid reaches the third (next to the bottom) mark. Note the time interval measured and record in seconds. Note the temperature of test and record in degrees Celsius.

Step.3: In the calibration of the instrument, make at least three determinations of the time of flow on each of three separately prepared beds of the standard sample. The calibration shall be made by the same operator who makes the fineness determination.

5. Calculations:

Calculate the specific surface values in accordance with the following equations:

$$S = S_s \sqrt{T} / \sqrt{T_s}$$

where

S = specific surface of test sample
S_s = specific surface of standard sample
T = measured flow time for test sample
T_s = measured flow time for standard sample
Corrections factors are applied when different test conditions are used.

EXPERIMENT # 9: TESTS OF CEMENT CONSISTENCY AND SETTING TIME

1. Consistence of standard cement paste: B.S 12, ASTM C-187
2. Initial and final setting times of Portland cement: B.S 12, ASTM :C191-70

1- Scope:

1. Making Normal Consistence cement paste.
2. Measuring the initial setting time and the final setting time of the standard consistence of the cement paste.

2- Apparatus & Materials:

1. VICAT Apparatus.
2. Digital weighing scale, used to measure the weight of dry cement.
3. Glass graduates, used to measure the volume of water.
4. Trowel.
5. Mixing bowl.
6. Stop-watch.
7. Portland Cement.
8. Water.

About the VICAT Apparatus:
It consists of the following:
1. Ruler starting from 40 mm (which is the height of the mould).
2. The Mould.
3. Non-porous plate.
4. The plunger.

Needles of penetration:

1. For making the normal consistence of standard paste we use a plunger with 10mm

diameter.

2. Initial setting needle, 1mm in diameter. Used in the determination of the initial setting time.
3. Final setting needle, it is a needle with a metal attachment hollowed out so as to leave a circular cutting edge 5mm in diameters and set 0.5mm behind the tip of the needle.

3- Procedures:

Part I: Normal consistency.

1. Weigh 650 grams of cement using the digital weighing scale. Be aware of subtracting the weight of the mixing bowl from the total weight we obtain.
2. Measure an amount of water (let’s start with 150 mm3) of water using the glass graduate. (This amount of water is nearly 26%-33% of the amount of cement).
3. Mix the obtained cement with the obtained water together in the mixing bowl. (The mixture should be homogenous and totally mixed during 4.25).
4. Fill the mould of the VICAT apparatus with the mixed cement, the surface of the paste should be smoothed off level with the top of the mould as quickly as possible.
5. We place the mould in its place in the VICAT apparatus and we use the 10mm diameter plunger, we lower it till it touches the paste and then we leave it falling freely.
6. We take the depth from the VICAT ruler, if the depth is between 5-7 mm then we got the standard paste with normal consistency, otherwise we do other trial with fresh cement.

Part II: Setting time measurement.

1. Once we determine the normal consistency, we can use the taken specification of that paste to measure the initial and final setting times. So we make a fresh cement paste using the amount of water and cement of the standard consistency. The stop-watch shall start at this step.
2. We use the 1 mm diameter needle, and penetrate the sample with this needle by leaving it to free fall, and then we read the VICAT ruler scale. We do a trial each 15 minutes until the depth of penetration is 5 mm. The elapsed time from mixing the water with dry cement till this moment is called initial setting time.
3. We replace the needle with another angular one (Final setting needle), and penetrate the sample by it every 15 minutes till only the needle makes an impression on the paste surface but the cutting edge fails to.

4- Discussion:

Part I: Normal consistency.

We made three trials to achieve our result of the normal consistency using fresh cement in each trial.

Amount of water (%)						
Penetration (mm)						

Part II: Setting time measurement.

Time (min)									
Penetration (mm)									

The initial setting time is …………………

The final setting time is …………………….

Conclusion:

EXPERIMENT # 9: MECHANICAL MIXING OF HYDRAULIC CEMENT PASTES AND MORTARS OF PLASTIC CONSISTENCY

ASTM Standard: ASTM C305 – 06

1. Scope

This practice covers the mechanical mixing of hydraulic cement pastes and mortars of plastic consistency.

2. Significance and Use

This practice is intended for use in the mechanical mixing of pastes and mortars for the testing of hydraulic cements.

3. Apparatus

3.1 Mixer—The mixer shall be an electrically driven mechanical mixer of the epicyclic type, which imparts both a planetary and a revolving motion to the mixer paddle. The mixer shall have a minimum of two speeds, controlled by definite mechanical means. (140 ± 5 r/min, with a planetary motion of approximately 62 r/min. The second speed shall revolve the paddle at a rate of 285 ± 10 r/min, with a planetary motion of approximately 125 r/min.) and equipped with :

- Paddle—The paddle shall be readily removable, made of stainless steel, and shall conform to the basic design shown in Fig. 2.
- Mixing Bowl—The removable mixing bowl shall have a nominal capacity of 4.73 L, shall be of the general shape and comply with the limiting dimensions shown in Fig. 3,

3.2 Scraper—The scraper shall consist of a semi rigid rubber blade attached to a handle about 150 mm long.

3.3 Supplementary Apparatus—The balances, weights, glass graduates, and any other supplementary apparatus used in measuring and preparing the mortar materials prior to mixing

4. Temperature and Humidity

4.1 The temperature of the room shall be maintained between 20 and 27.5 °C , and the temperature of the dry materials, paddle, and bowl shall be within the above range at the time of test. The temperature of the mixing water shall not vary from 23 °C

4.2 The relative humidity of the laboratory shall be not less than 50 %.

5. Procedure for Mixing Pastes

Step 1: Place the dry paddle and the dry bowl in the mixing position in the mixer. Then introduce the materials for a batch into the bowl and mix in the following manner:

Step 2: Place all the mixing water in the bowl.

Step 3: Add the cement to the water and allow 30 s for the absorption of the water.

Step 4: Start the mixer and mix at slow speed (140 ± 5 r/min) for 30 s.

Step 5: Stop the mixer for 15 s and during this time scrape down into the batch any paste that may have collected on sides of the bowl.

Step 6: Start the mixer at medium speed (285 ± 10 r/min) and mix for 60 s.

6. Procedure for Mixing Mortars

Step 1: Place the dry paddle and the dry bowl in the mixing position in the mixer. Then introduce the materials for a batch into the bowl and mix in the following manner:

Step 2: Place all the mixing water in the bowl.

Step 3: Add the cement to the water; then start the mixer and mix at the slow speed (140 ± 5 r/min) for 30s.
Step 4: Add the entire quantity of sand slowly over a 30s period, while mixing at slow speed.
Step 5: Stop the mixer, change to medium speed (285 ± 10 r/min), and mix for 30 s.
Step 6: Stop the mixer and let the mortar stand for 90 s. During the first 15 s of this interval, quickly scrape down into the batch any mortar that may have collected on the side of the bowl; then for the remainder of this interval, close the mixer enclosure or cover the bowl with the lid.
Step 7: Finish by mixing for 60 s at medium speed (285 ± 10 r/min).
Step 8: In any case requiring a remixing interval, any mortar adhering to the side of the bowl shall be quickly scraped down into the batch with the scraper prior to remixing.

EXPERIMENT # 10: COMPRESSION TEST

Standards: ASTM: C 109

1-Scope

To measure the mechanical strength of cement by applying Compressive test on Cement-Sand mortar.

2. Significance and Use

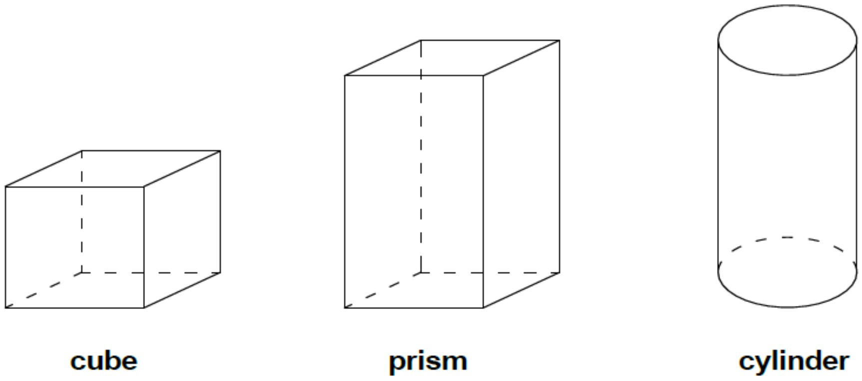
The success of any civil engineering project depends on quality control tests before, during and after construction. The behaviour of material under loading represents the response of the material to an external action. The main purpose of a mechanical test carried out on a specimen is to get properties, such as: compressive strength; modulus of elasticity (E-Young modulus), etc. The strength of material is the limit value (critical value) of a stress

3. Principle of the test

The prism halves (after test of flexural strength) are tested in compression Centre the prism halves laterally to the auxiliary platens of hard steel, which exactly determine the compressive area (because the prism halves have an irregular form). The size of the platens is 40 mm x 40 mm and they are at least 10 mm thick .During loading the relative attitude of the upper and lower platens shall remain fixed. The resultant of the forces shall pass through the centre of the specimen.

Materials testing to static loads

Axial compression: For this test, prismatic specimens, cubic specimens, cylindrical specimens, etc… are used.



Cube prism cylinder

For this test compression machines have been designed

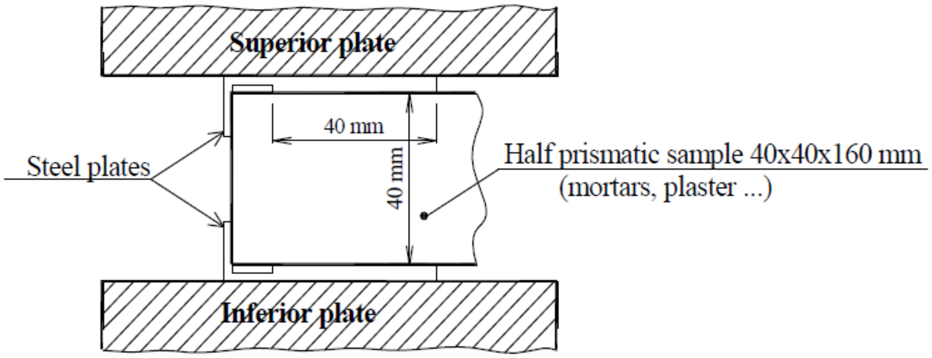
Compression test machine

Compressive strength σ is obtaining with formula:

$$\sigma = \frac{F_{max}}{A} \quad (\mathrm{N/mm^2})$$

where:
F_{max} : maximum load until crush sample, in N;
A : the surface load area, in mm^2.

The result is the average of the resistances obtained on minimum 3 samples. The samples are cleaned and will be placed between the platens of the hydraulic testing machine so that the force direction of testing is perpendicular to placement direction. In figure below, the compression test on mortar samples is shown.



The compressive strength obtained on mortar samples

Cube fracture

Cube fracture might be produced without cancelling friction between the machine plates and the cube surfaces in contact with these plates. In such a case, due to friction between the contacting surfaces, the tangential stresses developed at the contacting surfaces prevent the test sample from suffering strain. This fact is responsible for an increment in the cube strength. The fracture of the test specimen is produced by the detachment of its lateral parts following inclined planes at 30o with respect to the vertical; two butt-ended truncated pyramids are thus formed.
Friction between contacting surfaces is usually prevented by applying a paraffin layer, by interposing lead leafs or cardboard, etc. In such a case, transverse swelling of the cube is free to develop over its whole height and fracture takes places due to the cracks being initiated in the direction of compressive stress, as in the case of prismatic specimens. In the latter case, the ultimate strength value is lower than in the preceding case and does not depend on the cube sizes. Romanian Standard Specifications require that concrete class should be tested with no attempt to prevent friction between contacting surfaces.