

المسيلة في: 2025/06/12

رقم: 96 / م.هـ / 2025

شهادة إدارية

بخصوص تقييم المطبوعة البيداغوجية المنجزة من طرف الأستاذة: بوعلام سعيدة

بعد الاطلاع على تقارير الخبراء المعينين من طرف أعضاء اللجنة العلمية لقسم الهندسة المدنية ضمن اجتماعها المنعقد يوم الثلاثاء عشرون من شهر ماي عام ألفين وخمسة وعشرون ميلادي، قصد إنجاز خبرة حول المطبوعة البيداغوجية المقدمة من طرف الاستاذة بوعلام سعيدة، أستاذ محاضر "أ" بقسم الهندسة المدنية بجامعة محمد بوضياف والمعنونة ب:

Guided practical work

Practical work on the material strength

(Support pédagogique destiné aux étudiants de 2^{ème} année Licence en Génie Civil)

حيث أن كل تقارير الخبراء كانت إيجابية، تم المصادقة على المطبوعة واعتمادها لطلبة السنة الثانية ليسانس هندسة مدنية.

تكون لجنة الخبراء المعينة من طرف أعضاء اللجنة العلمية للقسم من السادة الآتية أسماءهم:

الأستاذ: شيكوش محمد عزيز أستاذ محاضر "أ" بجامعة محمد بوضياف بالمسيلة

الأستاذ: بوقرة خير الدين أستاذ محاضر "أ" بجامعة محمد بوضياف بالمسيلة

الأستاذ: دبوشة الصادق أستاذة محاضرة "أ" بجامعة البشير الإبراهيمي ببرج بوغريريج.

تستعمل هاته الشهادة فيما يسمح به القانون

رئيس القسم



رئيسة اللجنة العلمية للقسم



MINISTRY OF HIGHER EDUCATION AND SCIENTIFIC RESEARCH

Université Mohamed Boudiaf - M'SILA
Faculty of Technology
Civil Engineering Department



Guided practical work
The material strength
2nd Year (Licence of Civil Engineering)



Directed by : Dr. BOUALLEG. SAIDA

Academic Year : 2024/2025

SOMMAIRE

- PREFACE

CHAPTER I : WP .1 : Tensile tests

I.1 Introduction.....	1
I.2 Principle.....	1
I.3 WP Objective	2
I.4 Theoretical background.....	3
I.4.1 Hooke's Law.....	3
I.4.2 Elastic and Plastic Behaviour	4
I.5 Calculation assumption	4
I.5.1 The strength of material σ_m	4
I.5.2 The yield strength σ_e	4
I.5.3 StrainBand strain at break (relative elongation ϵ and ϵ_m).....	4
I.5.4 Young's modulus E	5
I.6 Equipment.....	6
I.6.1 Experimental set-up	6
I.6.2 Conducting the tensile test.....	7
I.7 Required work	8
I.8 Test results	9

CHAPTER II : T.P II : Single compression test

II.1 Introduction.....	10
II.2 General information on concrete	10
II.3 Purpose of the test.....	11
II.4 Principle of concrete compression testing	11
II.5 Compression test device	11
II.6 Standardized test pieces used in the compression test	12
II.6.1 Behaviour of materials under compression load	12
II.7 Stress-strain diagram.....	13
II.8 Test steps	14
II.9 Results	14

CHAPTER III : W.P III : Torsion test

III.1 Introduction.....	16
III. 2 Concept	16
III.3 Aim of the experiment	17
III.4 Test principle	18
III.5 Experimental measurement devices.....	18
III.5.1 Comparator measurement	18
III.5.2 Description of Equipment	19
III. 6 Work required	20
III.7 Résultats.....	21

CHAPTER IV : WP. IV : Simple Bending

IV.1 Introduction	22
IV.2 Aim of the experiment.....	22
IV.3 Test principle	22
IV.4 Experimental study.....	23
IV.4.1 Description of equipment	23
IV.5 Test procedure	24
IV.6 Experimental measurement devices	24
IV.6.1 Comparator measurement	24
IV.7. Work required	25
IV.8 Results	27

CHAPTER V : WP. V : Resilience test

V. Introduction.....	32
V.2 Purpose of impact testing	32
V.3 Definition of test principle	33
V.4 Test machine - Mouton Charpy	34
V.5 Test Flow	34
V.6 Test Pieces.....	35
V.6.1 CHARPY U.	35
V.6.2 CHARPY V	36
V.7 Specimen Notch Effect	37
V.8 Temperature Effect.	38
V.9 Characteristics of the impact test device	38
V.10 Conduct of the test	40

V.11 Work Required	40
V.12 results	40

CHAPTERS VI : WP. VI : Hardness tests

VI.1 Introduction.....	42
VI.2 Purpose.....	42
VI.3 objective.....	42
VI.4 Principle of the test.....	42
VI.5 Test machines and test pieces.....	43
VI.6 Hardness test methods.....	43
VI.6.1 Brinell hardness (HB).....	43
VI.6.2 Rockwell (HR) hardness test	44
VI.6.3 Ball test	45
VI.6.4 Diamond cone test	45
VI .6.5 Vickers hardness test (HV).....	45
VI.7. Test Flow	46
VI.8 Work required	47
Bibliographical references	48

PREFACE

This Guided practical work manual is intended for civil engineering undergraduate students in the second year of the new system. These résistance of Materials (W.P) have as main objective to develop in the student the interest of knowing certain specific properties metals by respecting the standards in force and especially to get acquainted with a key metal in the field of civil engineering : Put the student live with laboratory techniques.

The student has acquired basic notions in terms of W.P on metals, it is necessary to deepen his knowledge by more specific tests on concretes.

We have shown in this polycopy a series of W.P. suitable to the metals available for a good exploitation and understanding of the material of the present guided practical work.

CONTENT OF THE MATERIAL :

WP. I : Tensile tests

WP. II : Single compression test

WP. III : Torsion test

WP. IV : Simple bending test

WP. V : Resilience test

WP. VI : Hardness test

Evaluation mode :

Report : 100%.

It is written in a simplified way, given notions so that the student can assimilate the content of practical work and have a clear vision of its application in Everyday life.

The student must be able to use the different metals and describe all relevant standards according to the following conditions, criteria and specifications ;

- Good knowledge of metals.
- Proper use of each metal (Standard) in the different parts

DERAILMENT OF WP :

Location of WP :

The WP take place in the premises of the faculty of technology, Laboratory of Civil Engineering, « Materials » on the ground floor.

Before each session :

The student must have read and understood the part of the booklet related to T.P, to be able to follow properly the explanations of the teaching during the start-up.

Questions about handling or Equipment used should be asked at that time.

During the session:

Students must follow the instructions given in the booklet and by the teacher, for completion.

As for the use of the devices, in some cases, in addition to the explanations given on the manual, students will learn from teachers

At the end of session :

Each group of students cleans their Workplace. At the next session (or within one week).

Each group will report on the technique used during the WP, and on the results obtained. This report must be well written (presentation noted) no delay will be tolerated.

This report on succinct to have the following schema :

- ✓ Introduction
- ✓ Purpose and principle of the technique
- ✓ Results and interpretations (this part should specify the operating conditions)
- ✓ Conclusion- Advantages, disadvantages of the technique.

Importante note :

The various devices made available to students during the WP are high-tech, precise and therefore fragile, and consequently expensive to buy and maintain. Special attention is therefore required for their handling.

Rating :**The W.P note includes :**

- ✓ An appreciation of the practical work done during TP sessions
- ✓ And, an assessment of the ability to write, synthesize and interpret the results obtained in manipulations.

CANEVA ;

Semestre : 4

Unité d'enseignement : UEM 2.2

Matière 5 : TP RDM

VHS : 15h00 (TP : 1h00)

Crédits : 1

Coefficient : 1

Objectifs de l'enseignement : Mettre en application les différentes notions étudiées dans les matières « Résistance des matériaux » du semestre en cours.

Connaissances préalables recommandées : Résistance des matériaux.

Contenu de la matière :

Travaux pratiques : Résistance des matériaux

TP N°1. Essais de traction

TP N°2. Compression simple

TP N°3. Essai de torsion

TP N°4. Essai de flexion simple

TP N°5. Essai de résilience

TP N°6. Essai de dureté

Mode d'évaluation : Contrôle continu : 100%.

CANEVAT ;

Semester: 4

Teaching unit : EMU 2.2

Subject 5 : WP RDM (RM)

VHS : 15h00 (WP: 1h00)

Credits: 1

Coefficient : 1

Teaching objectives : To apply the different concepts studied in the subjects « Resistance of materials » of the current semester.

Recommended background knowledge : Strength of materials.

Content of the subject :

Practical work : Strength of materials

TP N°1. Tensile tests

TP N°2. Simple compression

TP N°3. Torsion test

TP N°4. Simple bending test

TP N°5. Resilience test

TP N°6. Hardness test

Evaluation mode : Continuous control : 100%

PRACTICAL WORK I :

PW. I

Tensile tests

CHAPTER I : WP .1 : Tensile tests

I.1 Introduction :

The mechanical properties of metals and alloys are of considerable interest since they not only condition all problems of forming materials but also their behaviour in service in extremely diverse applications. For a given problem, the choice of a material will depend on mechanical properties such as strength, hardness or ductility, and it is therefore necessary to measure them with a number of experiments called mechanical tests.

The tensile test consists in placing a small bar of the material to be studied between the jaws of a tensile machine which pulls on the bar until it breaks. The elongation and applied force are recorded, which are then converted into deformation and stress.

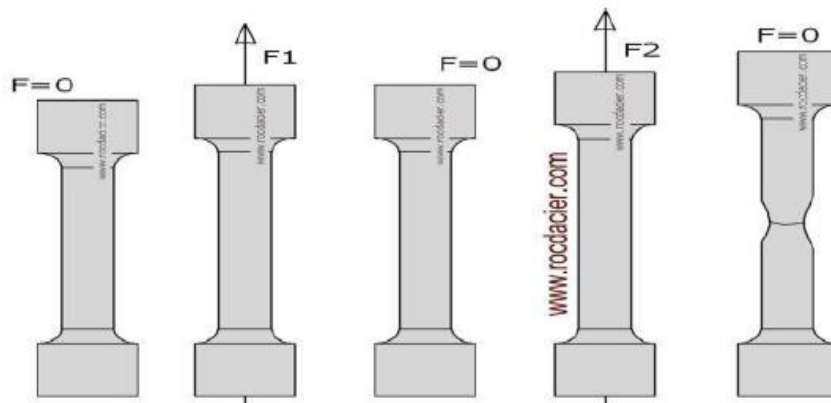


Figure 1. Tensile process.

These tests have several objectives: They allow, first of all, to study the physical laws that govern the mechanical behavior of materials and are therefore a very effective research tool.

I.2 Principle:

The tensile test consists of subjecting the specimen (Fig.) to an elongation load which increases monotonously until rupture. In a first step, the load required for elongation of the specimen increases rapidly enough until the elastic limit of the material is reached. The rest of the deformation is obtained without the load increasing so significantly; this is the plastic phase of the deformation. In a Last step, the deformation is concentrated in a region of the body of the test piece until the rupture takes place, it is striction.

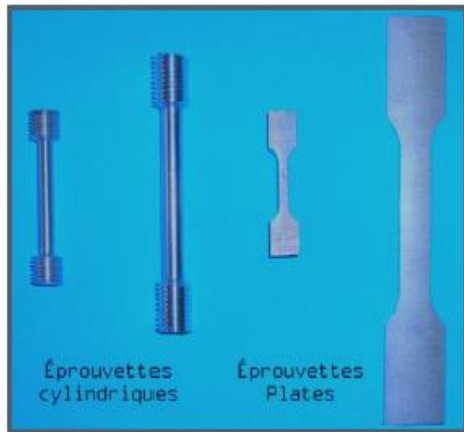
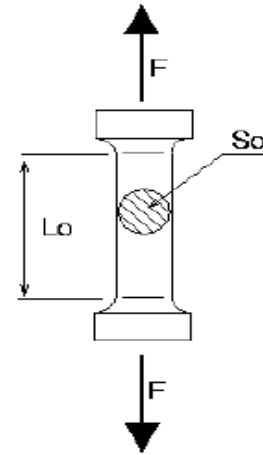


Figure 2. Tensile specimen model



Lo: initial length
So: initial section
 For a conventional specimen,
 We have: $L_0 = 5.65 \cdot (S_0)$

I.3 WP Objective:

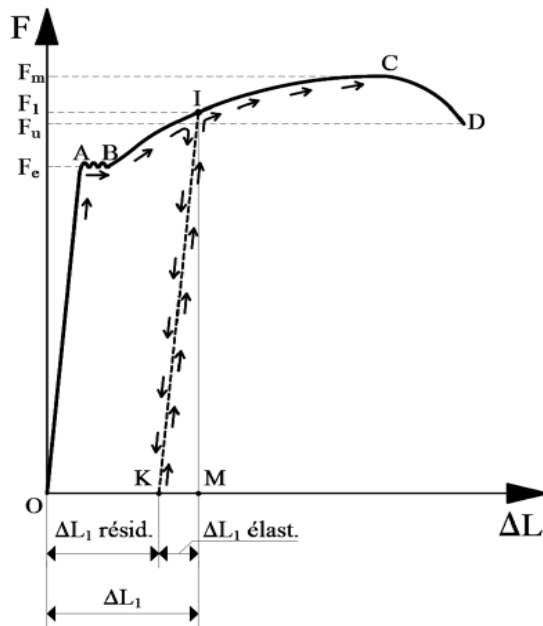
The main objective of this test is to plot the material behaviour curve in uniaxial tensile stress/deformation. The latter allows subsequently to deduce several parameters of the material in question such as:

- The Young's modulus, E , or longitudinal elasticity modulus, expressed in megapascals (MPa)
- The yield stress (where it exists), R_e , σ_e , σ_y or f_y (yield stress), which is used to characterize a conventional field of reversibility;
- Tensile strength R_m , σ_m or f_u (ultimate limit), which defines the limit at rupture;
- Elongation at break $A\%$, which measures the capacity of a material to stretch under load before breaking, an interesting property in certain applications;
- The coefficient of Poisson ν , which corresponds to the ratio between the transverse deformation (section decrease) and the longitudinal deformation (relative elongation) of the part in the elastic field.

- Tensile curve :

The tensile test makes it possible to draw a curve showing the evolution of the applied stress ($\sigma = \text{force}/\text{section}$) in relation to the deformation ($\epsilon = \text{relative elongation}$) (see figure 3).

This curve is called a tensile curve from which the characteristics can be deduced, Depending on the material, temperature and deformation speed, the tensile curve can have different shapes. Figure 3 shows the tensile curve of a mild steel.



A: Elastic phase limit.
 C: maximum load point that marks the beginning of striction.
 D: Test specimen breaking point.
 Fe: load at the apparent yield point.
 Fm: maximum load.
 Fu: ultimate charge.
 $\Delta l=L-L_0$ =Absolute elongation with L.
 Useful length of the test piece (as a function of tensile force)

Figure 3. Stress-strain diagram Mild steel.

From the tensile test we obtain the tensile curve, of which three different ranges can be distinguished (Fig.3):

- Part OA represents the elastic range, so the tensile curve is a straight line. The slope of this line gives the Young's modulus E and Fe represents the elastic limit load.
- From point A onwards, the curve inflects and represents the beginning of the plastic range. Point B represents the elastic limit Fe.
- Point C represents the maximum load Fm, corresponding to the maximum tensile stress (load).
- Point D corresponds to specimen failure and is characterized by the ultimate load FU the Fracture load.

I.4 Theoretical background

I.4.1 Hooke's Law

In the elastic domain, Hooke's Law states that strain is proportional to applied stress. This relationship is expressed by the following equation :

$$\sigma = E \cdot \epsilon$$

Where:

σ : Stress (in MPa or N/mm²),

E : Modulus of elasticity (in MPa or GPa),

ϵ : Strain (without unit). It translates the relationship of proportionality between stress and deformation in the first segment of curve OA, hence σ in MPa, E in MPa and ϵ without unit.

I.4.2 Elastic and Plastic Behaviour :

Elastic: In this phase, the material returns to its original state after removal of the load.

Plastic: Beyond the yield point, the material undergoes permanent deformations.

Rupture: The rupture is the point where the material can no longer withstand the stress applied. It can be ductile (with great deformation) or brittle (sudden rupture).

I.5 Calculation assumption:

The quasi-static application of load avoids the intervention of other dynamic phenomena, and the shape of the specimen and the transverse direction of the load lead to a uniform distribution of the force over the cross section of the specimen, what makes it possible to determine the stress and elongation and the following parameters :

I.5.1 The strength of material σ_m

The maximum strength of the test corresponds to the material resistance, this resistance is also known by the tensile strength σ_m and is calculated through the maximum force observed during the F_m test and the initial cross section of the S_0 test piece as follows:

$$\sigma_m = F_m / S_0$$

I.5.2 The yield strength σ_e :

Yield stress is the stress corresponding to the point at which the proportionality between stress and strain deformation stops. Because of the difficulty of determining it, a simple way of determining it. In accordance with the tensile test standard, this value is value is conventionally taken at a strain equal to 0.2%. Explicitly, the conventional yield point is taken as the intersection of the curve with the straight line parallel to the elastic phase passing through the 0.2% strain.

I.5.3 Strain at break (relative elongation ϵ and ϵ_m) :

Relative elongation (ϵ) characterizes the variation, length of the test specimen compared to its initial length (Original L_0). It is known from the deformation and is calculated by the following formula :

$$\epsilon = \frac{L - L_0}{L_0} \times 100\%$$

Looking for the relative elongation (strain) of the specimen at break ϵ_u , we replace with the final or corresponding length at break L_u .

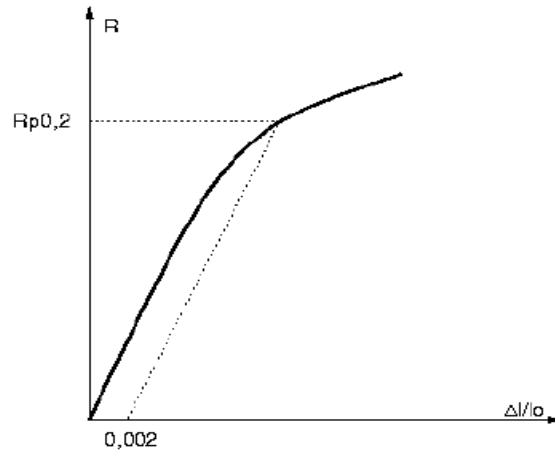


Figure 4. Détermination de la limite élastique.

I.5.4 Young's modulus E :

Young's modulus or modulus of elasticity (longitudinal) or tensile modulus is the constant that links tensile (or compressive) stress and the onset of deformation in a material. It is the ratio between the tensile stress applied to a material and the resulting deformation (relative elongation), as long as this deformation remains small and the material's elastic limit is not reached. This is the proportionality factor between stress and strain, and can be deduced from the following formula:

$$E = \sigma / \varepsilon$$

Knowing that :

- σ : is the stress (MPa) .
- E : is Young's modulus (MPa) .
- ε : is relative elongation, or strain.

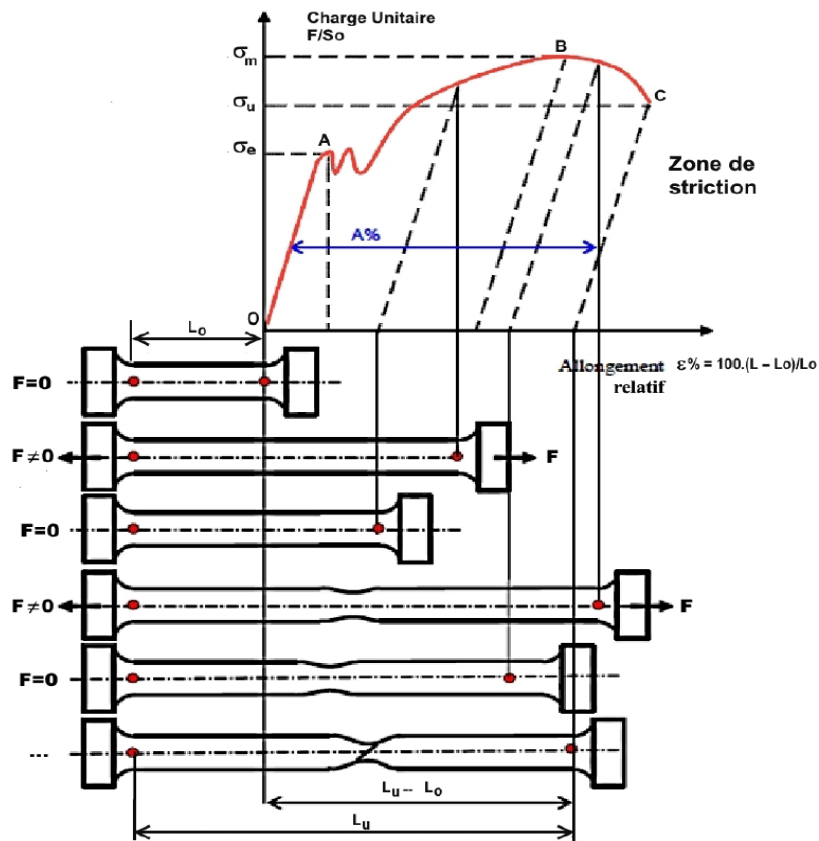


Figure 5. Elements of the conventional tensile diagram with two static loading-unloading cycles before and after ultimate load.

I.6 Equipment :

I.6.1 Experimental set-up :

The test is carried out on a universal hydraulic machine (fig 5). The test tube used is cylindrical or prismatic. One end of the test tube is attached to a special part mounted on the machine frame (fixed part), while the other end is connected to another part mounted on the moving crosshead. The movement of the crosshead is controlled by a hydraulic cylinder. This is driven by oil pressure supplied by a motor pump unit. A force indicator shows the value of the load applied. A device mounted on the machine can be used to plot the load curve as a function of crosshead movement.



Figure 6 : Diagram of the traction machine.

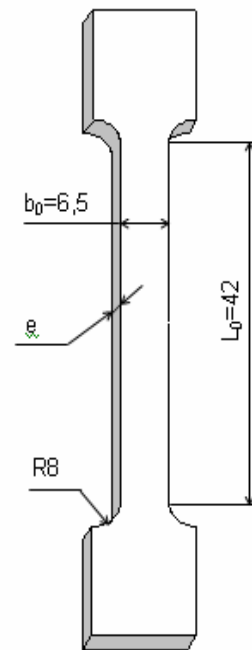


Figure 7. Tensile test specimen.

The following table gives a few examples of material characteristics, indicating the type of bonding between microscopic elements that ensures cohesion in this material.

feature material	R_e	R_m	A%	link
Diamonds	50000 MPa	-	0	Covalent
Glass	3600 MPa	-	0	Covalent
Steele	150 à 4000 MPa	400 à 4000 MPa	10 à 30%	Metal
Aluminium	40 MPa	200 MPa	0 à 40%	Metal
Polyethylene	10 MPa	20 MPa	10 à 1000%	Faible

Table 1. Examples of material characteristics.

I.6.2 Conducting the tensile test :

- Take the initial dimensions (length and diameter of the working area) of the test specimen (use the caliper).
- Operate switch to switch on machine (lever must be in off position).
- Lower the moving crosshead to the level of the top end of the test piece by Moving the lever in the downward direction (fairly high speed).

- Attach the test piece to the moving crosshead.
- Set the crosshead speed to a low value.
- Set the operating valve to the “up” position and allow to rise slowly.
- Monitor load indicators.
- Return the operating valve lever to the “off” position when the test piece breaks.
- Read the breaking load value.
- Dismantle the two parts of the test piece and join them to measure the final length.
- Calculate material characteristics using appropriate expressions.

I.7 Required work :

-Measurements of physical quantities relating to tensile tests:

S_0 : Surface area of initial specimen

L_0 : Length of specimen before tensile test, L_u : Length of specimen after rupture

S_u : Surface area of specimen after rupture

On the tensile machine, take displacement measurements as a function of force.

-Elastic range :

a. Draw the two curves $F(\Delta L)$ and $\sigma(\epsilon)$.

- 1) Import the test file into a table.
- 2) Plot the force vs. displacement curve.
- 3) Plot Stress (MPa) versus Strain (%).
- 4) Deduce the material's characteristic constants:

- Young's modulus E
- Yield strength R_e
- Mechanical strength R_m
- Elongation at break $A\%$.
- Strain coefficient.

5) Analyze the shape of the fracture zone. Do the specimens break in tension or shear.

Points	1	2	3	5	6	7	9
F(N)							
Δl (mm)							
$\sigma=F/S_0$ (MPa)							
$\epsilon=\Delta l/l_0$							
$E=\sigma/\epsilon$ (MPa)							

b. Determine the Young's modulus E (MPa) of the specimen material.

3. Elasto-plastic range

I.8 Test results :

Material	d ₀ [cm]	L ₀ [cm]	S ₀ [cm ²]	F _e [kN]	F _m [kN]	R _e [kN/cm ²]	R _m [kN/cm ²]	L _f [cm]	A [%]	E [kN/cm ²]
Steel I	0.804	4.8	0.704	50	54	71.03	76.72	5.504	15.70	
Steel II	0.8	4.7	0.702	21	28	29.91	39.88	6.17	30.13	
Alloy Al_I	0.806	4.8	0.705	22	25	31.22	35.47	5.25	8.47	
Alloy Al_II	0.803	4.642	0.703	21	26	29.85	36.96	5.25	13.18	

PRACTICAL WORK. II

PW. II

Simple compression

CHAPTER II : T.P II : Single compression test

II.1 Introduction :

One of the aims of materials science is to enable an optimum choice of Construction Materials (CM) used in the realization of a project, taking into account economic and safety conditions.

Any value that can be used to determine a given characteristic is called a property. Knowledge of the mechanical properties of materials enables us to predict their ability to withstand various loading conditions.

The main properties of M.D.C. include :

- Mechanical properties : stress, strength, deformation, plasticity,
- Physical properties : dimensions, density, porosity.
- Chemical properties : resistance to corrosion, acids, etc.

In terms of mechanical behavior, materials generally do not respond in the same way to the different loads to which they are subjected (bending, torsion, tension, compression, etc.). Experimentation enables us to determine the material's ultimate strength prior to fracture. In This tutorial, we examine the resistance of concrete to compressive loading.

II.2 General information on concrete :

Concrete is the most widely used material in the world today, more than all other materials combined. Without concrete, we wouldn't be able to build the housing, schools, hospitals, transport infrastructure, etc. that we do today. Both robust and universal, it can be used anywhere, in any country.

Concrete is made by mixing cement, water and aggregates extracted from quarries or rivers. The various types of aggregate are mixed with the cement in specific proportions to ensure that there is as little “void” in the concrete as possible.

Water is used to make the concrete, and must occupy as much of the surface area around the cement molecules as possible in order to play its role as a binder. However, it must not be used in excess, as once its role is fulfilled it will evaporate, leaving a “void” known as porosity.

This porosity will reduce the concrete's strength. The chemical reaction that enables cement concrete to set is slow: barely 50% of final strength after 7 days. The value used as a reference in calculations is that obtained at 28 days (80% of final strength). Concrete has a much higher compressive strength than tensile strength.

Mechanical resistance in compression is of the order of :

- 25 to 35 MPa for concrete manufactured on site (sometimes up to 50 MPa)

- 40 to 60 MPa for ready-mix concrete, carefully concreted in the factory (prefabrication)
- Up to 200 MPa for high-performance concrete.

II.3 Purpose of the test :

- Determination of compressive yield stress for brittle materials.
- Construction of the compression curve.
- Draw a diagram of the specimen before and after deformation or breakage.

II.4 Principle of concrete compression testing :

The strength of concrete is measured by subjecting previously prepared test specimens to a slowly monotonically increasing compressive load until failure. Figure 1 shows the state of loading of the specimen in compression (fig 1).

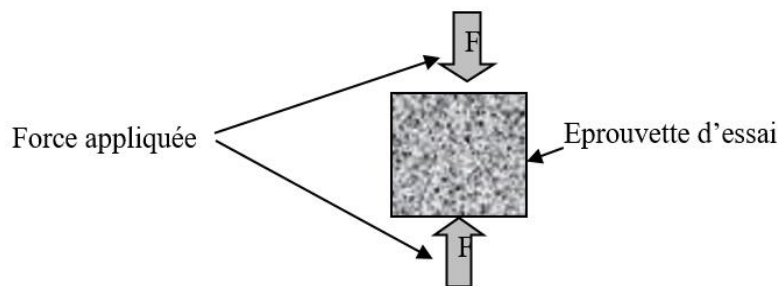


Figure 1 . Schéma de principe de sollicitation en compression.

II.5 Compression test device :

The test device is generally a fairly powerful hydraulic press (figure 2).

The test chamber consists of a rigid frame connected to the upper cross-member by four very sturdy cylindrical columns. The hydraulic cylinder, located in the center, carries at its upper end a plate which is used to place the test specimen.

The compression force is applied to the test specimen, whose upper face is pressed against the machine's fixed cross-member by the cylinder controlled by the power unit. The specimen is thus subjected to an increasing axial load (5 bar/s) until it breaks (crushes). The breaking load is recorded on an appropriate indicator.

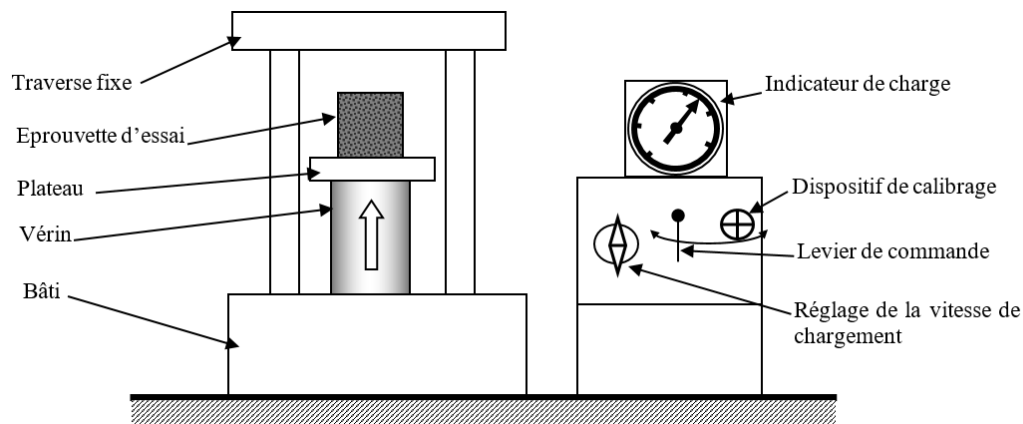


Figure 2: Schematic diagram of concrete compression test device.

The test pieces, manufactured in special moulds, are generally cubic or cylindrical.

- The test pieces in cubic form are made with dimensions of 10 cm or 15 cm side.
- The cylinder-shaped test pieces are 16 cm in diameter and 32 cm high.

These test pieces are subjected (usually 28 days after they have been made) to a crushing force and the effort required to break the test piece is measured.

The value of the ratio of the crushing force to the cross-section of the test piece gives the compressive strength of the concrete.

II.6 Standardized test pieces used in the compression test :

There are three types of standardized test pieces:

1. Long test pieces of about 8 to 10 times the diameter of the straight section of the test piece ($L_0 = 8d$ to $10d$) ; they are used to schematically represent the constrained behavior – deformation of a given material and to determine its limits of proportionality and flow.
2. Medium-sized test pieces with a length equal to three times the diameter of the section ($l_0 = 3 d_0$); they are used for determining tensile strength
3. Short test pieces ($l_0 = 0.9 d_0$); used for testing metals intended for the manufacture of supports in order to estimate the influence of friction on them.

II.6.1 Behaviour of materials under compression load:

When a cylindrical low-carbon steel specimen is compressed, it takes the form of a barrel (fig.3, b). The compression curve obtained for this material is shown in Figure 4.

The fracture type of a cast-iron specimen subjected to axial compression is shown in Figure 5 and the corresponding compression curve is given in Figure 6.

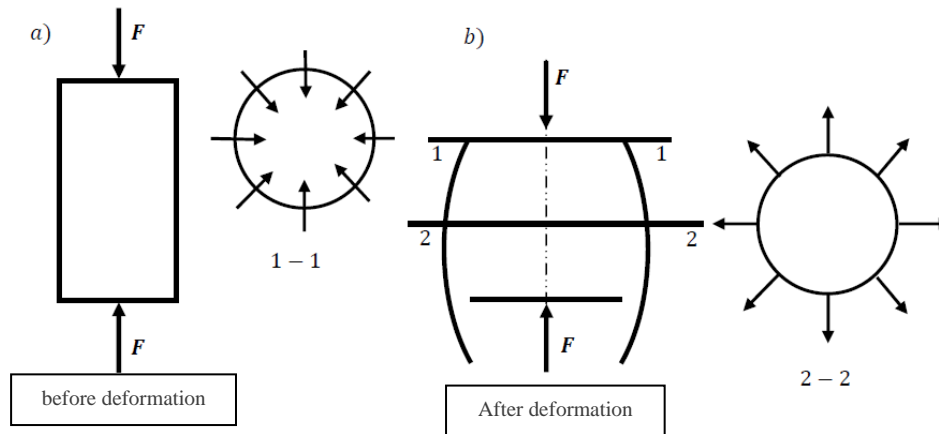


Figure 3. Concrete specimen.

The load-displacement diagrams, obtained from axial compression tests performed on a cube-shaped piece of wood, are shown in Fig.7.

- 1- Compression in the direction of the fibres .
- 2- compression in the direction perpendicular to the fibres).

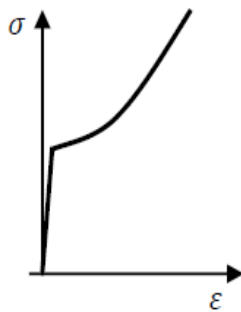


Fig .4



Fig .5

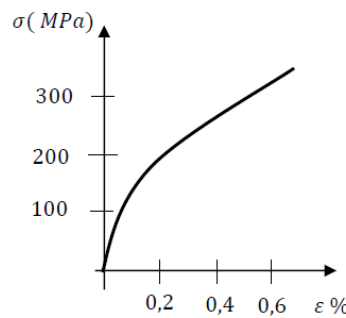


Fig. 6

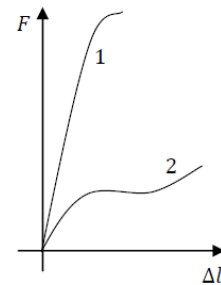


Fig.7

The test pieces used in the compression test must meet the Following requirements :

- The length of the test piece must not exceed ten times its diameter (10 10d0), in order to avoid the phenomenon of buckling.
- The faces of the test piece (in contact with the machine plates) must be well polished, flat, parallel and perpendicular to its axis, so that the load is axial and the frictional forces are minimized.

II.7 Stress-strain diagram :

As we have already seen, the shape of the curve describing the behaviour of the material under compression depends on the nature of the material it self. For example, ductile metals do not do not break, for such materials the test must be terminated after major plastic

deformations have been obtained or once the maximum load developed by the machine is reached.

For semi-ductile metals and brittle metals, the ultimate strength can be achieved and therefore calculated. It should be noted that semi-ductile metals may or may not have a flow bearing, depending on the metal processing conditions of the test piece, whereas fragile materials do not, for which only the ultimate compressive stress can be calculated.

The equations giving respectively the stress and the compression deformation are then written

$$\sigma = F/S_0 \quad \text{and} \quad \epsilon = \Delta L / L$$

F ; the compression load,

S_0 ; initial section of the test piece

L_0 ; initial length of the test piece, ΔL variation in length

II.8 Test steps :

- 1.Place the test specimen in the test chamber (make sure the specimen is centered),
- 2.Switch on machine (press start button),
- 3.Set the piston feed speed to a fairly high value and move the control lever to the “load” position,
- 4.When the top surface of the test piece has almost reached the fixed crosshead, stop piston movement (zero speed),
- 5.Select the loading speed according to the dimensions of the test specimen (2.5 for specimen (15x15x15) cm³ and 2.2 for specimen (10x10x10) cm³ the specimen will be subjected to an increasing compression load (5 bar/s),
- 6.Read the value of the breaking load when the specimen breaks,
- 7.Unload the specimen (control lever in “unload” position),
- 8.Remove test tube and clean place.

II.9 Results :

Test1: Cylindrical specimen vLoading speed = 3.2 cm/s

Diameter d = 16 cm, i.e. cross-section $S = 0.02 \text{ m}^2$.

Height h = 32 cm

Breaking load $F = 340 \text{ kN} = 340000 \text{ N}$

Compressive strength $R = \text{load}/\text{section} = 17\text{MPa}$

Test 2: cubic specimen, loading speed = 3.4 cm/s

Side = 10 cm, i.e. cross-section $S = 0.01 \text{ m}^2$.

Breaking load $F = 400 \text{ kN} = 400000 \text{ N}$

Compressive strength $R = \text{load/section} = 40\text{MPa}$

PRACTICAL WORK. III

PW. III

Torsion test

CHAPTER III : WP. III : Torsion test

III.1 Introduction

Torsion is a typical stress for structural components. The resulting stresses and strains can lead to failure. The choice of factors such as material, cross-section, length and type of support can have a major influence on the stability of structures.

This paper examines the influence of these factors on the deformation of a bar subjected to torsional loading. If, of all the internal forces, only the moment M_x (M_t) is present, it causes torsion. This type of loading is very common in mechanical structures.

When a torsional moment is applied, the bars twist around their axis. Torsional deformation is also described by its torsion angle. According to Hooke's law, the angle of twist is proportional to the external torsional moment.

III.2 Concept

In an orthonormal frame of reference (o, x,y,z), consider a cylindrical beam of radius (r_{max}) and length (L), hinged at one end and free at the other. The axis of the beam coincides with axis (x), as does the axis of the torsional moment M_t (fig1).

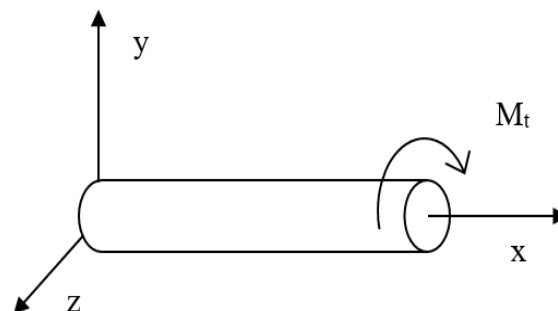


Figure. 1 Simple torsion load diagram.

The beam is said to be subjected to simple torsion if, at the center of gravity of each straight section of the beam, only the torsional moment M_t is non-zero.

Under the action of the torsional moment M_t (fig. 2), adjacent cross-sections rotate in relation to each other. The generatrix AB then assumes the position AB', forming an angle (θ).

Under these conditions, two sections (dx) apart rotate relative to each other through an angle ($d\theta$) such that:

$$d\alpha = \theta \cdot dx$$

$$d\theta = d\alpha/dx$$

(θ)denotes the unit angle of twist in $^{\circ}/\text{m}$ ou rad/m .

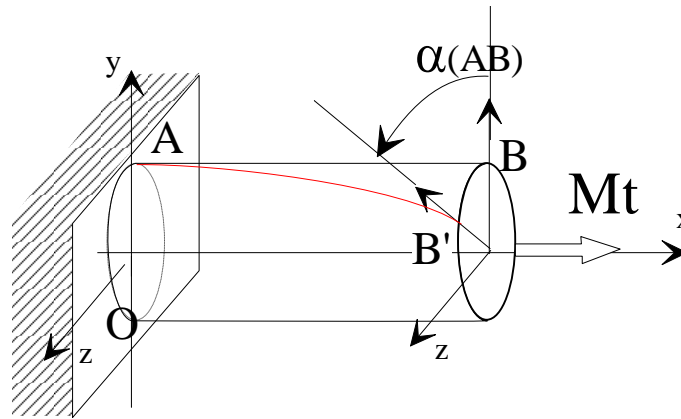


Figure. 2 Torsional deformation.

The stress generated in this case is a tangential stress (θ) whose value at any point on the part is proportional to the unit twist angle (θ) and the distance (r) of this point from the axis (x).

$$\tau = G.r.\theta \dots\dots\dots (1)$$

G is a material constant (transverse modulus of elasticity). The deformation equation for simple torsion is written :

$$M_t = G.\theta.I_0\dots\dots\dots(2)$$

Where I_0 is the polar quadratic moment. For a circular section of diameter (d), we have :

$$I_0 = \frac{\pi.d^4}{32} \dots\dots\dots(3)$$

The stress at any point is :

$$\tau = \frac{M_t.r}{I_0} \dots\dots\dots(4)$$

The stress is greatest at the points of the section furthest from the center.

$$\tau_{\max} = \frac{M_t}{W_p} \dots\dots\dots(5)$$

Where $W_p = I_0 / r_{\max}$ is the section's polar modulus of inertia.

r_{\max} being the radius of the beam's circular cross-section.

III.3 Aim of the experiment :

The aim of this experiment is to study the torsion of straight beams. It highlights the following points :

- Study the relationship between the torsional moment and the torsion angle of a bar.
- Investigate the relationship between the fastening length and the torsion angle of a bar.
- Experimentally determine the value of the transverse modulus of elasticity G (or Coulomb's modulus) of the materials under consideration. Coulomb modulus) of the materials considered (steel, aluminum).

III.4 Test principle :

In this test, a torsional moment is applied to the free end of a cylindrical beam, the second end of which is rigidly embedded. The aim is to determine the effect of the value of the applied moment on the torsional deformation.

The torsional moment is obtained by applying a force (F) to the end of a rod of specified length fixed to the end of the free part of the beam (fig. 3). The force (F) corresponds to the action of the weight of a mass suspended at the end of the rod.

The deformation generated by the torsional moment is measured using a comparator positioned at a distance (s) from the center of torsion.

III.5 Experimental measurement devices

III.5.1 Comparator measurement :

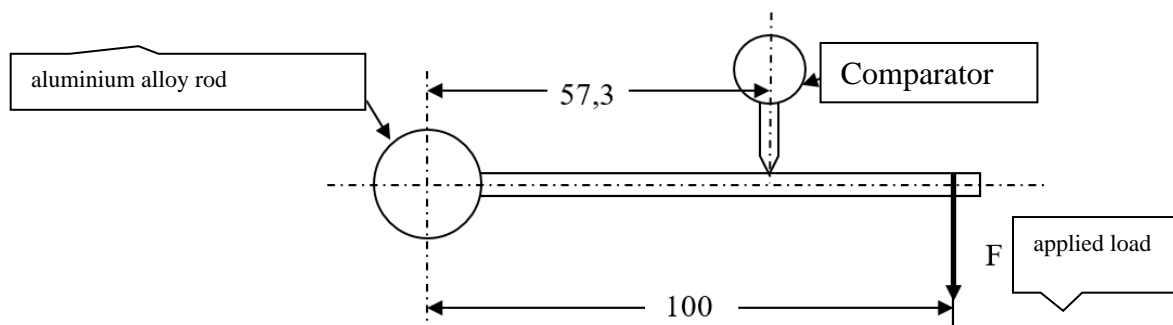


Figure. 3 Diagram of torsional moment realization.

Comparators or amplifiers are length-measuring devices. They do not indicate an absolute measurement, but a measurement relative to a reference point. They record the difference in dimensions between different points on a deformed part under external stress. The accuracy and sensitivity of these devices depend to a large extent on the consistency and low intensity of the pressure exerted on the part to be measured by their moving key. In the category of mechanical comparators, the dial gauge is the most widely used. The dial gauge (Fig 4) consists of .

- a large dial divided into 100 parts equal to 1/100th of a mm (dial gauges are also available with a reading of 1/1000th) ;
- a small dial (totalizer) which indicates the number of revolutions of the large pointer;
- the whole of the large graduation (bezel), which can be rotated around the axis of the watch, so that the “zero” division can be set at will in front of the central hand.

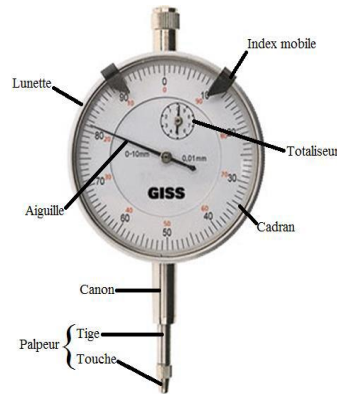


Figure .4 Dial gauge.



Figure. 5 Dial gauge.

III.5.2 Description of Equipment :

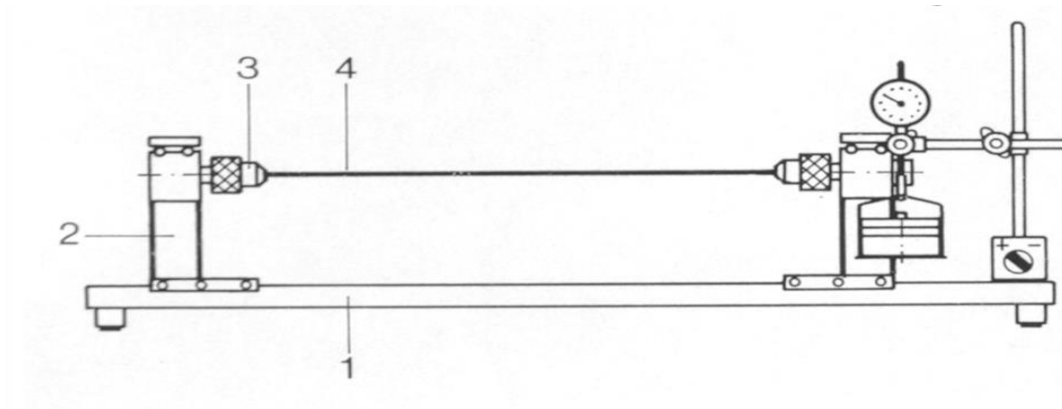


Figure 4. Torsion test bench.

-Ingrédients :

1. Bast
2. Bracket
3. Fixing mandrel
4. Torsion bar
5. Gauge
6. Weight

The steps involved in carrying out the test are as follows:

1-Measure the length and diameter of the bar to be used for the test. Note the alloy type of the bar.

2-Position the test fixture supports so that the distance corresponds to the length of the bar.

- 3-Insert one end of the bar into the Chuck and tighten using the special wrench.
- 4- Mount the loading device on the other end of the bar.
- 5-Position the measuring device using the magnet holder.
- 6- Set comparator to zero.
- 7- Place ground in loading device.
- 8- Read gauge indication.
- 9- Repeat steps 6 and 7 for different mass values and tabulate.
- 10- Show graphically the evolution of the torsion angle as a function of the applied moment.

III.6 Work required :

-Evolution of torsion as a function of moment

The beam used for this test is a cylindrical aluminum alloy rod with a diameter of 10 mm and a length of 400 mm.

The torsional moments correspond to the action of weights of mass $m = 0.1 - 0.2 - 0.5 - 1.0 - 1.5$ and 2.0 kg.

-Remarks :

1-Preliminary tests have shown that the test device undergoes a self-deformation which depends on the torque applied. The following table shows the values of the dial indicator readings as a function of test weight.

Loading weight in kg	0,1	0,2	0,5	1,0	1,5	2,0
Gauge indication in mm	0,01	0,02	0,045	0,095	0,155	0,205

These values must be taken into account when testing the aluminum alloy bar.

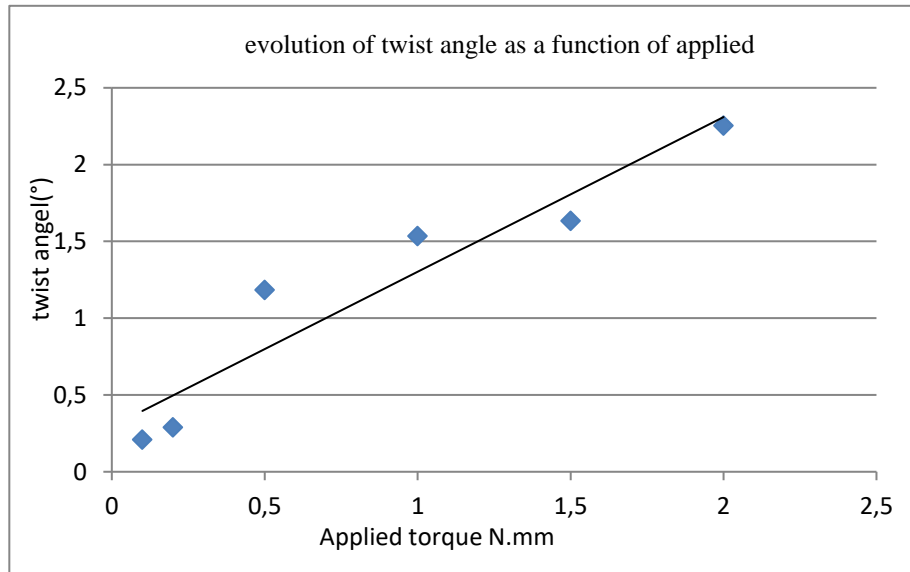
1. The location of the measuring gauge has been chosen so that 1 mm on the gauge represents a torsion angle of 1° .
2. The indications of the measuring gauge are given in the following table:

Loading weight in kg	0,1	0,2	0,5	1,0	1,5	2,0
Applied torque in N.m						
Gauge indication in mm						
Gauge indication in mm						
Bar torsion angle (θ)						

3. Plot the diagram as a function of Mt
4. Conclude.

III.7 Results :

Loading weight in kg	0,1	0,2	0,5	1,0	1,5	2,0
Applied torque in N.m						
Gauge indication in mm	0.22	0.31	1.23	1.63	1.79	2.46
Gauge indication in mm						
Bar torsion angle (θ)						



PRACTICAL WORK. IV

PW. IV

Simple bending test

CHAPTER IV : WP. IV : Simple Bending

IV.1 Introduction :

There are several types of bending, depending on the nature of the cohesive torsor. These depend, among other things, on the nature of the beam, the configurations of the external mechanical actions applied, pure bending, simple bending, compound bending and deviated bending. We will only discuss the case of simple bending, since it is the most frequently encountered type, and also because of the need for laboratory testing. Nevertheless, we will provide a brief overview of the different types.

Bending is the deformation of an object resulting in curvature (fig1). The bending test is a quasi-static mechanical test that characterizes the mechanical properties of the material under study. It is very easy to set up (no specimen clamping system, simple specimen geometry), and reproduces fairly well the common stresses to which industrial parts are subjected.

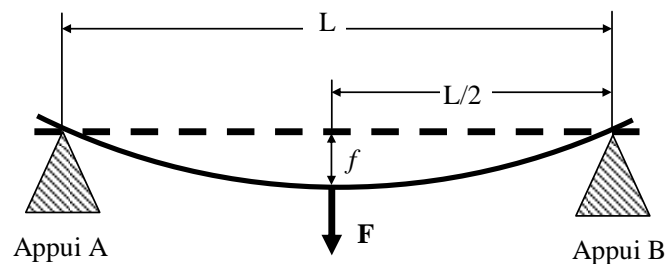


Figure. 1 schematic diagram of bending test.

IV.2 Aim of the experiment :

The aim of this practical work is to learn how to estimate the modulus of elasticity of a given material, constituting a beam, through a simple bending test. It also invites the engineering student to analyze the sensitivity of this parameter (modulus of elasticity) in relation to The geometric dimensions of the beam under test, i.e. :

- Its inertia
- Its span length
- The nature of its supports

For each bending test carried out on a given beam, the group involved in this project will Draw load curves, calculate deflections and finally determine moduli of elasticity.

IV.3 Test principle :

The “three-point” bending test determines the deformability of a material on two supports (A and B) separated by a distance (L), with the force (F) applied halfway between the supports

(fig. 2). The applied load deforms the beam. The displacement of the centerline results in a curvature with maximum deflection (f) at the point where the load is applied.

Study the influence of various factors, such as material, cross-section, embedding length and type of support, on the deformation of a bar subjected to a bending load or torsional moment.

In this case, the maximum deflection (f) is calculated as follows:

$$f = \frac{FL^3}{48.E.I} \dots\dots (1)$$

Where E : modulus of elasticity of the material (N/mm²).

$$I = \frac{b.h^3}{12} \text{ : moment of inertia of beam cross-section.}$$

Hence : $f = \frac{FL^3}{4.E.b.h^3} \dots\dots\dots (2)$

Where b : cross-section width and h : height.

IV.4 Experimental study :

IV.4.1 Description of equipment :

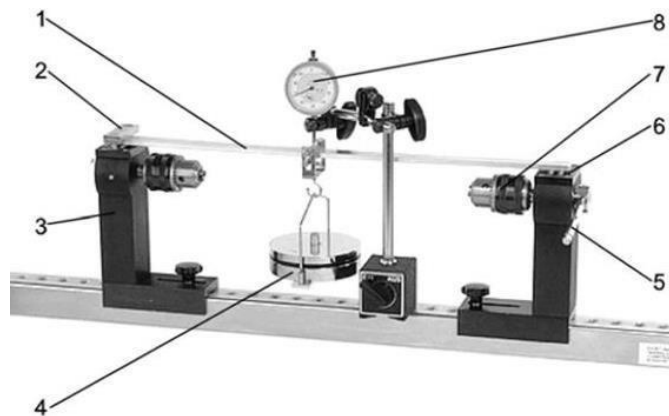


Figure 2. Bending machine.

-Ingrédients :

- 1- Beam.
- 2- Recess for bending test.
- 3-Support.
- 4- Weight.
- 5- Torsional moment release device.
- 6-Bearing for bending test.
- 7-Mandrel for torsion test.

8-Dial comparator.

IV.5 Test procedure :

Fix the test fixture supports at a distance of 500 mm from each other. The length of the test bar is 510 mm.

Before testing, mark the distances 500 mm and 250 mm with a pencil (see fig. 3).

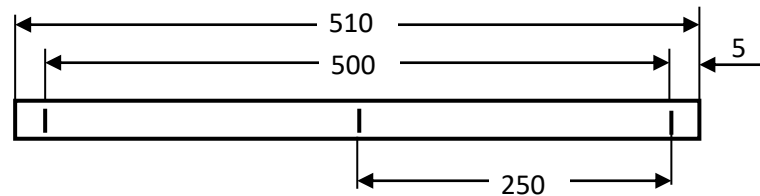


Figure. 3 marker markings.

1. Place the bar on the prismatic supports, leaving 5 mm from each end.
2. Fix the measuring device by placing the magnetic surface on the top of the frame.
3. Set comparator to “zero”.
4. Slowly place the load (1kg mass) in the measuring device tray.
5. Read arrow indication on dial indicator (red).

IV.6 Experimental measurement devices :

IV.6.1 Comparator measurement :

Comparators or amplifiers are length-measuring devices. They do not indicate an absolute measurement, but a measurement relative to a reference point. They record the difference in dimensions between different points on a deformed part under external stress. The accuracy and sensitivity of These devices depend to a large extent on the consistency and low intensity of the pressure exerted on the part to be measured by their moving key. In the category of mechanical comparators, the dial gauge is the most widely used. The dial gauge (Fig 4) comprises :

- A large dial divided into 100 parts equal to 1/100th of a mm (Dial gauges are also available with a reading of 1/1000th) ;
- A small dial (totalizer) which indicates the number of revolutions of the large pointer ;
- The whole of the large graduation (bezel), which can be rotated around the axis of the watch, so that the “zero” division can be set at will in front of the central hand.

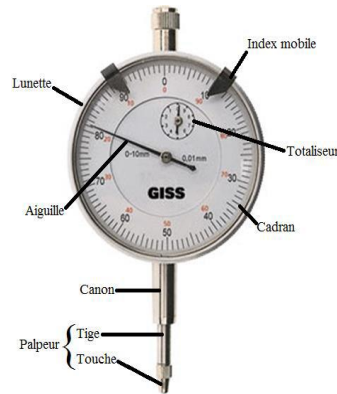


Figure .4 Dial gauge



Figure. 5 Dial gauge support.

IV.7. Work required :

-Manipulations :

1 - Study of deflection as a function of material stiffness

The test bars are made of different materials (Al, Cu, Brass, St). The specimens have the same cross-section (b=20mm, h=4mm) and the load applied corresponds to the weight of a 1kg mass. The distance between supports is 500 mm.

The deflection values for each bar are given in the Following table :

	Deflection measured on dial gauge (mm)	Calculated modulus of elasticity E (N/mm ²)	Module d'élasticité E donné par les tables (N/mm ²)
Aluminium alloy			70000
Copper alloy			125000
Alliage Cu- Zn (Laiton)			80000
Steel			210000

-The results can be used to plot the evolution of the value of the Arrow as a function of 1/E.

Note :

The modulus of elasticity can be determined using the formula : $E = \frac{FL^3}{48.I.f}$ (3)

Sachant que pour les barres prismatiques, le moment d'inertie $I = \frac{b.h^3}{12}$

2- Study of deflection as a function of specimen width.

The test specimens are prismatic aluminum alloy bars of different widths (b = 10, 15, 20, 25 and 30 mm).

The distance between supports is 500 mm and the load applied corresponds to the weight of a 1kg mass. (F =9.81 N) applied at mid-distance.

Specimen cross-section (bxh)	10x5	15x5	20x5	25x5	30x5
Measured deflection f (mm)					
$\frac{1}{b}$ en $\frac{1}{mm}$					

-Draw the graph showing the arrow (f) as a function of the ratio and draw your conclusion.

3- Study of deflection as a function of specimen height.

The test specimens used are rectangular-section aluminum alloy bars of different heights (h = 3, 4, 5, 6, 8 and 10 mm) and widths of 20 mm.

The distance between supports is 500 mm and the load applied corresponds to the weight of a 1kg mass. (F =9.81 N) applied at mid-distance.

Section (b x h)	20x3	20x4	20x5	20x6	20x8	20x10
Measured deflection (mm)						
$\frac{1}{h^3}$ en $\frac{1}{mm^3}$						

Draw the graph showing the arrow (f) as a function of the ratio and draw your conclusion.

4-Study of deflection as a function of applied load.

An aluminum alloy test bar with a cross-section of 20 x 5 mm is used.

The distance between supports is 500 mm and the loads applied correspond successively to weights of mass 0.5, 1.0, 1.5, and 2.0 kg.

Load weight (kg)	0.5	1.0	1.5	2.0
Deflection measured with dial gauge (mm)				

Draw the graph showing the evolution of the deflection (f) as a function of the applied load (F) and draw the following conclusion.

5 - Study of deflection as a function of distance between supports.

An aluminum alloy bar with a cross-section of 20 x 4 mm² is used.

The distances between supports are set at : L = 20, 30, 40 and 50 mm.

The load applied corresponds to the weight of a 1kg mass. (F =9.81 N) applied at mid-distance.

Distance between supports L (cm)	20	30	40	50
Deflection measured on dial gauge (mm)				
L ³ in cm ³				

-Draw the graph showing the evolution of the arrow (f) as a function of L^3 and draw your conclusion.

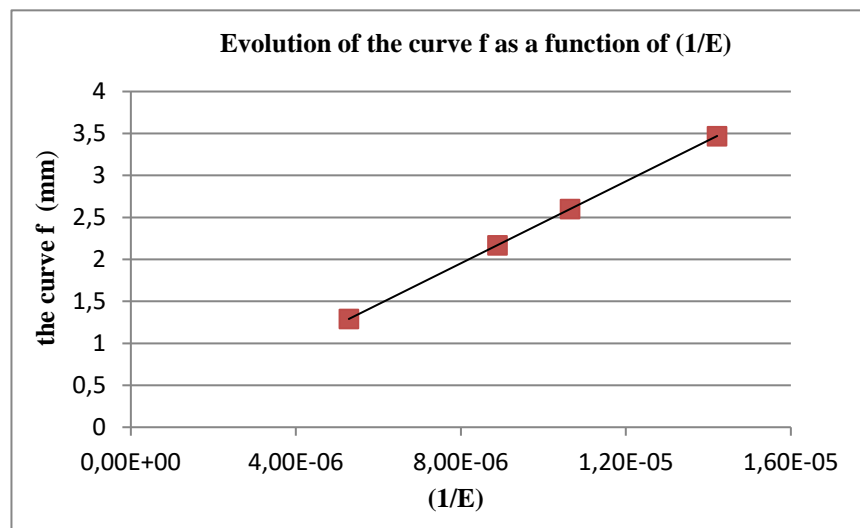
IV.8 Results :

1 - Study of deflection as a function of material stiffness

The test bars are made of different materials (Al, Cu, Brass, St). The specimens have the same cross-section ($b=20\text{mm}$, $h=4\text{mm}$) and the load applied corresponds to the weight of a 1kg mass. The distance between supports is 500 mm.

The deflection values for each bar are shown in the table below.

	Arrow measured on dial gauge (mm)	Calculated modulus of elasticity E (N/mm ²) $E = \frac{F.L^3}{48.I.f}$ et $I = \frac{b.h^3}{12}$	Modulus of elasticity E given by tables (N/mm ²)
Al	3.47	70358	70000
Cu	2.17	112507	125000
Laiton	2.60	93900	80000
St	1.29	189256	210000

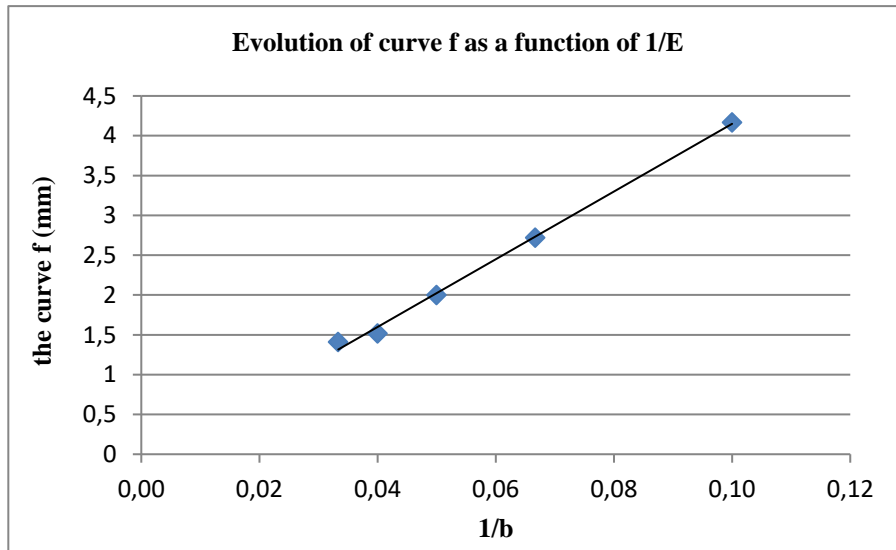


2 - Study of deflection as a function of specimen width.

The test specimens are prismatic Al alloy bars of different widths ($b = 10, 15, 20, 25$ and 30 mm).

The distance between supports is 500 mm and the load applied corresponds to the weight of a 1kg mass. $F=9.81$ N applied at mid-distance.

Section of the specimen (bxh)	10x5	15x5	20x5	25x5	30x5
Measured deflection (mm)	4.17	2.72	2.00	1.52	1.41
$\frac{1}{b}$ en $\frac{1}{mm}$	1/10	1/15	1/20	1/25	1/30

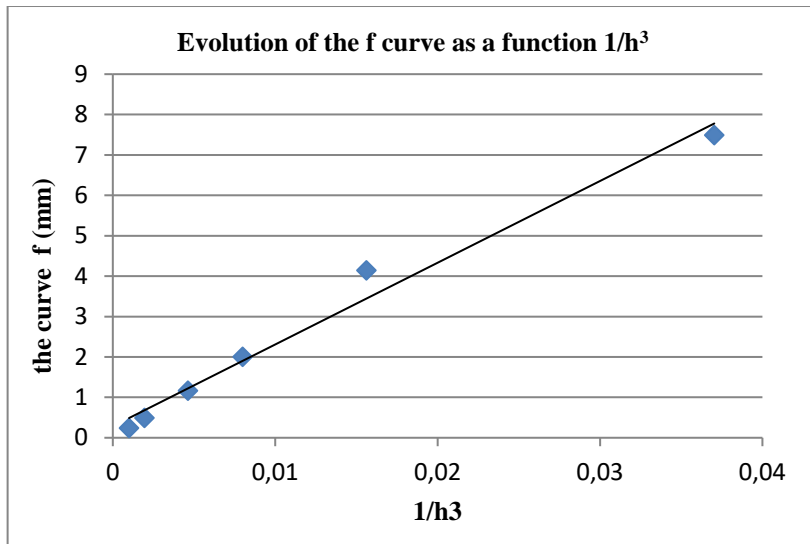


3- Study of the deflection as a function of the height of the specimen.

The test pieces used are aluminium alloy bars with a rectangular cross-section of different heights (h = 3, 4, 5, 6, 8 and 10 mm) and a width of 20 mm.

The distance between the supports is 500 mm and the applied load corresponds to the weight of a mass of 1kg. (F = 9.81 N) applied at half-distance.

Section (b x h)	20x3	20x4	20x5	20x6	20x8	20x10
Measured deflection (mm)	7.49	4.14	2.00	1.16	0.49	0.24
$\frac{1}{h^3}$ en $\frac{1}{mm^3}$	0.03703704	0.015625	0.008	0.0046	0.002	0.001

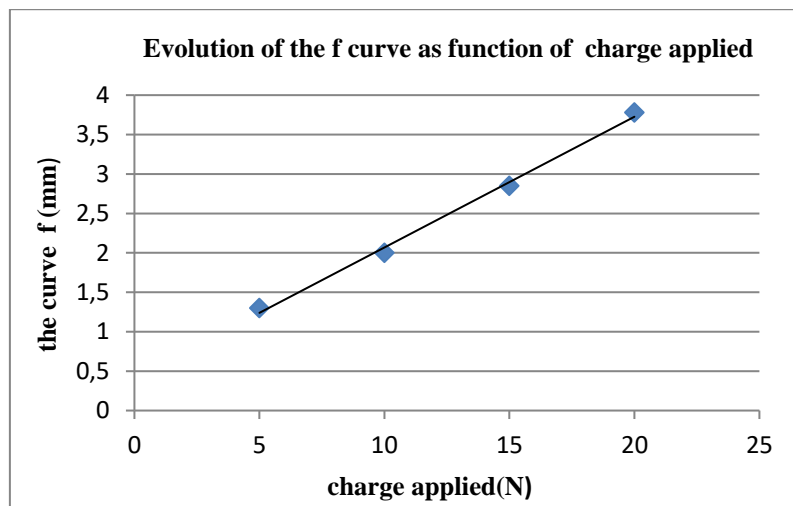


4-Study of deflection according to the applied load.

An aluminum alloy test bar with a cross-section of 20 x 5 mm is used.

The distance between the supports is 500 mm and the loads applied correspond successively to the mass weights 0.5, 1.0, 1.5, and 2.0 kg.

Masse du poids de chargement (kg)	0.5	1.0	1.5	2.0
Déflexion mesurée au comparateur (mm)	1.3	2.00	2.85	3.78



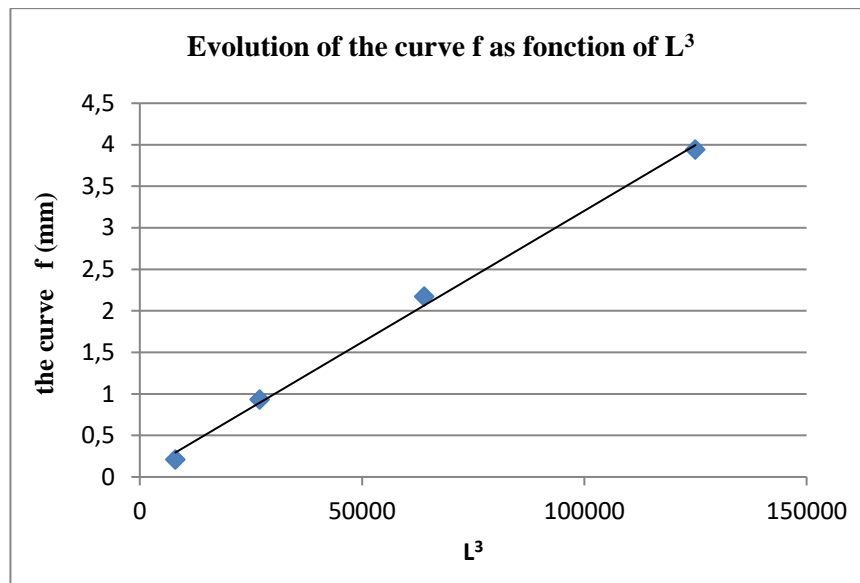
5- Study of deflection as a function of the distance between the supports.

An aluminum alloy bar with a cross-section (20 x 4) mm² is used.

The distances between the supports will be set to: L = 20, 30, 40 and 50 mm.

The applied load corresponds to the weight of a mass of 1kg. ($F = 9.81 \text{ N}$) applied at half-distance.

Distances entres les appuis L (cm)	20	30	40	50
Déflexion mesurée sur le comparateur (mm)	0.21	0.93	2.17	3.94
L^3 en cm^3	8000	27000	64000	125000



PRACTICAL WORK IV:

WP. IV

Resilience test

CHAPTER V : WP. V : Resilience test

V.1 Introduction :

Resilience characterizes the ability of a material to resist fracture under impact. The resilience test, also called impact test, allows to determine this characteristic for a notched sample

In-service breakdowns are extremely costly and can result in loss of human life, time and cost. Examples include :

- the impact of mechanical parts of an aircraft landing gear.
- The impact of the drilling tool which can be worth a considerable time and cost for its change. It is therefore important to be able to characterize this phenomenon satisfactorily experimentally. On the other hand, it has been found that certain materials, particularly heat-treated steels, are liable to rupture under shock loads.

The resilience test is a test that allows to study the ability of materials to withstand shock loads by measuring the energy absorbed by the rupture; resilience, therefore, is the determination of fragility or ductility.



Figure 1. Landing gear failure on impact.

V.2 Purpose of impact testing :

The Charpy impact test is used to measure impact toughness, i.e. to characterize the embrittlement of a material. It involves breaking a notched specimen (the purpose of the notch is to embrittle the material) - a Charpy specimen. Under the impact of a “sheep-pendulum”, the energy required to break the specimen is measured by the difference between the start and

end positions of the pendulum. This energy is reduced to the cross-sectional area of the specimen to give the resilience value. It is usually expressed in Joules/cm².

V.3 Definition of test principle :

The resilience test (impact test) consists in breaking, by a single impact, a specimen previously notched in its middle, and measuring the energy W (in joules) absorbed by the break. Resilience is defined by the letter K (Joules/cm²).

The test is carried out on a machine known as a rotary pendulum impact tester. The impact resistance of the material is measured. The test is carried out in accordance with the following standards : EN 10045 :1990, EN 8752 and NFA 03-161, etc. The impact test consists of striking a specimen of standardized shape and dimensions using a pendulum of known weight moving at a predetermined speed. The energy absorbed in breaking the specimen (in a single blow) is measured, giving an indication of the notch impact strength of the material tested. The impact test is carried out on a machine known as the “Charpy Sheep”, the schematic diagram of which is shown in figure 2.

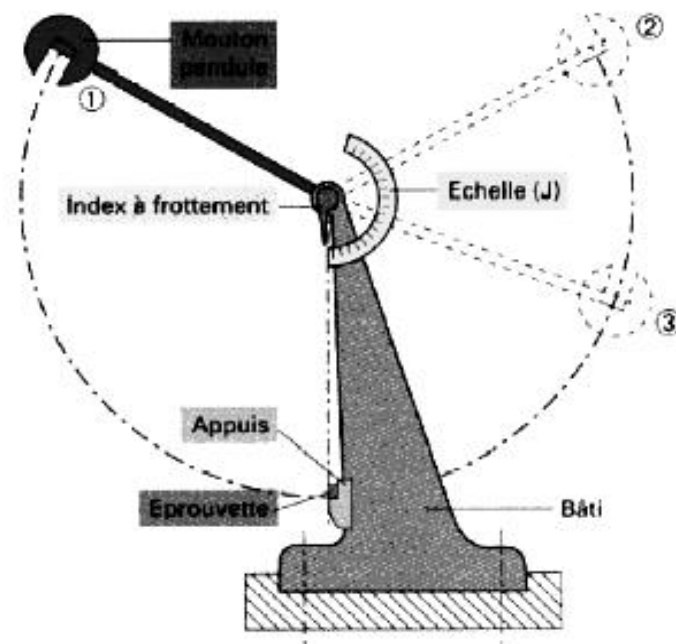


Figure 2. Schematic diagram of the Charpy sheep.

-1 : starting position of the sheep

-2 : final position of the sheep without test specimen.

-3 : final position of the sheep after rupture of the test specimen.

These tests show that materials can be classified as “brittle” or “ductile”. A brittle material will absorb less energy in the impact test than a ductile material. Brittle fracture is

characterized by the absence of macroscopic plastic deformation, and therefore by very rapid crack propagation with low energy consumption. Fracture is clean-cut, following crystallographic planes, known as cleavage fracture. This is the case for ceramics, low-temperature centric cubic metals and certain low-temperature polymers.

V.4 Test machine - Mouton Charpy :

The Charpy sheep consists of a knife attached to a hammer which oscillates in a vertical plane around an axis (Fig. 3). For a test, the knife is brought to a height H corresponding to the starting energy... $WH = mg H$. In its fall, the knife will cause the specimen to break, which will be accompanied by an absorption of energy K_v , and the hammer will rise to a height H' to which is associated a potential energy $WH' = mg H'$ It then simply comes: $K_v = WH - WH'$. The lower the height H' , the more resilient the material.

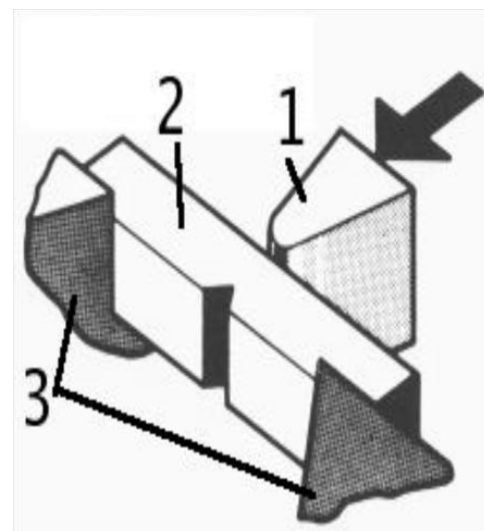
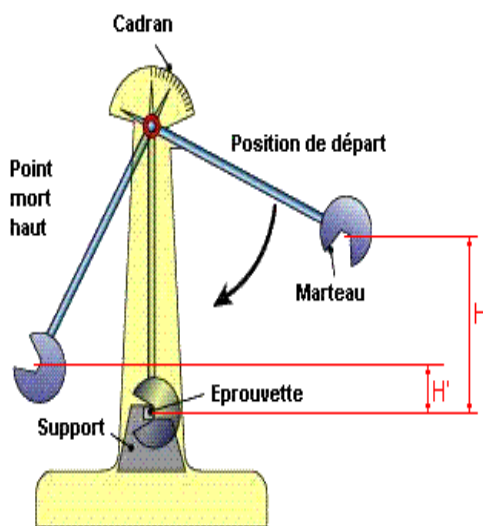


Figure 3. Mouton Charpy

Breakdown diagram :

- 1. Knife 2. Test tube 3. Supports

Donc, l'énergie K_v dépensée pour rompre l'éprouvette (les frottements étant négligés) vaut :

$$K_v = WH - WH' = P (H - H') = mg (H - H')$$

The resilience is defined as the energy of rupture (under shock) brought back to the section S of the specimen at the crack location : K_v/S in (J/cm^2) .

V.5 Test Flow :

The test shall be carried out at an ambient temperature, unless otherwise specified if the temperature is not specified in the specification, a temperature equal to $23^{\circ} \pm 5$ shall be taken. The test piece shall be placed on the supports of the Charpy sheep in such a way that the head of the sheep's knife comes to strike it in the plane of symmetry of the cut and on the opposite side to thec For the normal test "nominal energy of the sheep shall be 300 joules + 10. If during the test "specimen does not break completely, the value obtained for resilience is

uncertain, in this case it will be necessary to mention « Specimens not broken by x joules» and the angle of fracture of the part will be noted.

V.6 Test Pieces :

A Charpy test piece is a bar of square or rectangular section. Two types of test pieces exist, the KCV and KCU test pieces, according to the notch has a shape of U or V. which will be used for breaking by a sheep (mass) at the end of a pendulum. The dimensions of the test piece, as well as the test conditions (mass and speed of the pendulum shear) are strictly standardized. The essential differences between these types of test pieces are the surface of the material tested (respectively between 0.5 and 0.8 cm²) and the radius of curvature of the notch and thus the triaxial stress. The U test pieces are practically no longer used and are only used for comparisons with old results (in particular thermal ageing).

V.6.1 CHARPY U :

Is a machined bar of square section of 10 mm of side and whose length is 55 mm. The notch of 2 mm width and 5 mm depth ends in a cylindrical bottom of 1 mm radius. Resilience is then measured and specified according to the KU symbol.

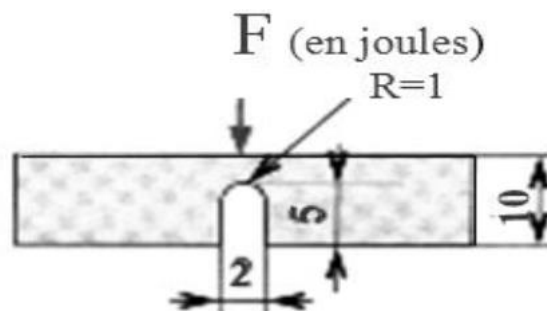


Figure 4 . U-shaped sample, symbol KCU.

Specimen dimensions according to NFA 03-161

Length : 55 \pm 0.6

Width : 10 \pm 0.09

Height : 10 \pm 0.11

Notch angle : 42 \pm 2°

Notch radius : 1 \pm 0.07

Notch depth : 5

V.6.2 CHARPY V Test Pieces

For a test with a Charpy V specimen, the specimen shall be notched in a 2 mm deep V and at an angle of 45° of which the dimensions are the same as for the Charpy U specimens. The symbol KV specifies the V-resilience test.

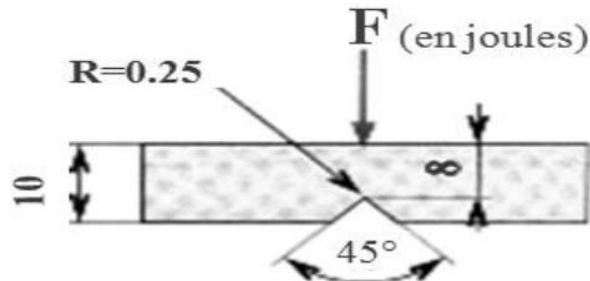


Figure 5. V-shaped test piece, symbol KCV.

Specimen dimensions according to NFA 03-161

Length: 55 ± 0.6

Width: 10 ± 0.06

Height: 10 ± 0.11

Notch angle: $42 \pm 2^\circ$

Notch radius: 0.25 ± 0.025

Notch depth: 2

Brittle rupture can also occur for abnormal conditions such as:

- Low temperature,
- High speed application of the load,
- Pre-existing or in-service defects

The sample can be made with a “U” or “V” notch. The U-shaped notches are reserved for fragile materials, while the test pieces with V-shaped notches are used for testing ductile materials.

The standard Charpy-V specimen shown in Figure 6 has a length of 55 mm, a cross-section (10×10) mm² and a depth of 2 mm with a rounded bottom of 0.25 mm.

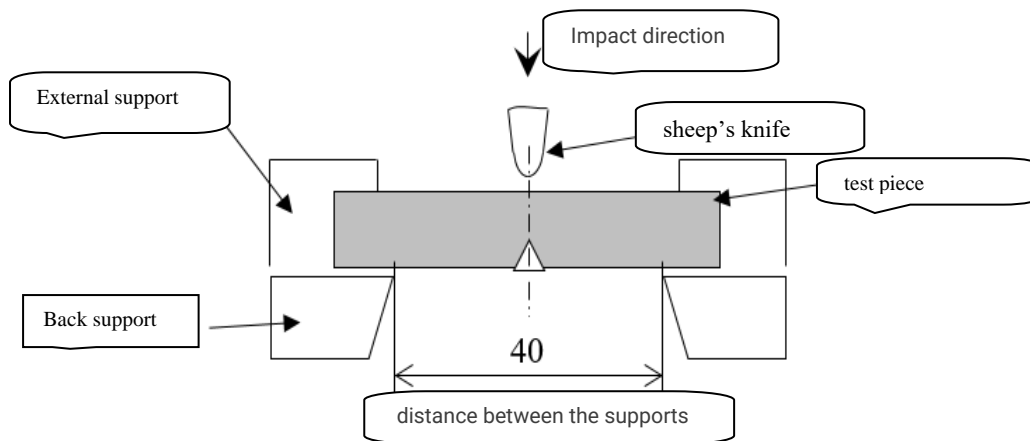


Figure 6. Drawing for positioning the notch test piece.

V.7 Specimen Notch Effect

The effect of the shape of the test piece on the breaking energy is very pronounced. The purpose of the notch is to ensure a state of triaxial stress, already during the initiation of the crack, rather than to cause the notch effect. For this reason, the bottom of the notch is not sharp but cylindrical (rounded) (radius of 0.25 or 1 mm depending on the type of specimen). The area of the section remaining at the notch is, according to the definition of resilience, the section to be used for its value calculation. The two test pieces are not equivalent. The breaking energy (in J) and resilience (in J/cm²) vary with the depth of the notch and the radius of curvature at the bottom of the notch. If the full radius of the notch is varied, the concentration and triaxiality of the stresses at its end are modified. The resilience is minimal for an acute crack (radius = 0, notch effect) and increases with the radius (figure.4).

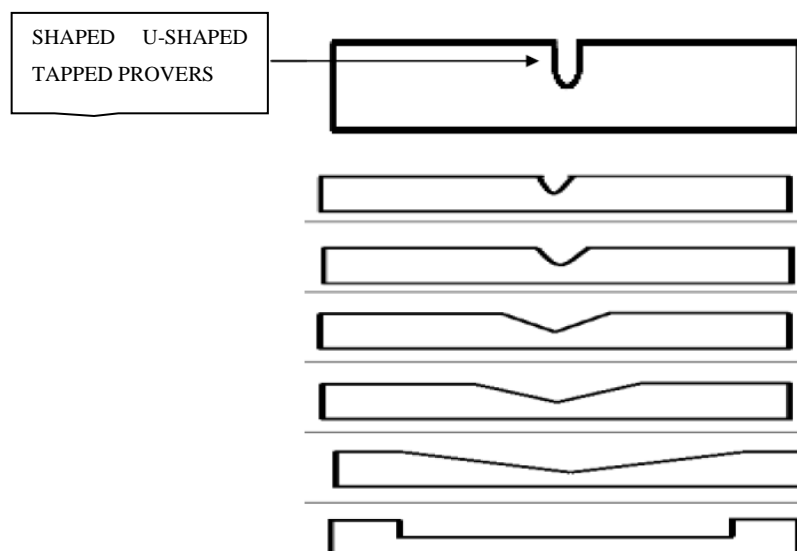


Figure 7. Test tube shapes.

Radius of curvature at the bottom of the cut (mm)	Breaking energy (en J)
Acute crack (r = 0)	5.4
0.17	9.5
0.34	11.3
0.68	18.6

Table. 1 Influence of the cut-off radius on the breaking energy Of a mild steel test piece, depth 5 mm.

V.8 Temperature Effect

The measurement of the absorbed break energy varies with temperature. At high temperature, the breaking energy is relatively high, which corresponds to a ductile rupture. When the temperature drops, the value of the breaking energy drops considerably, which corresponds to a fragile break.

The appearance of the failure surface reveals the nature of the fracture and can facilitate determination of the ductile-brittle transition temperature. A ductile fracture produces a fibrous (matte) surface, while a brittle fracture produces a glossy surface. These two types of characteristics are present in the ductile-brittle transition (Fig 8).

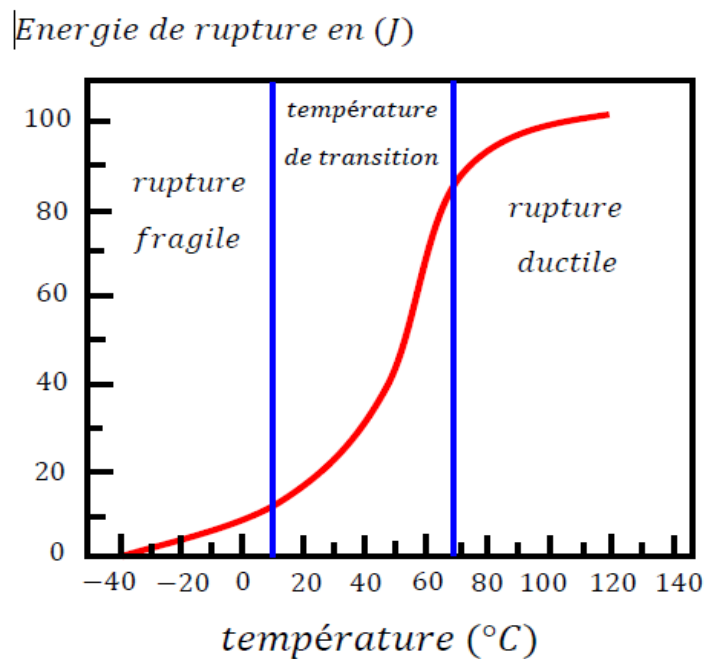


Figure 8. Temperature effect on the breaking energy of a mild steel specimen.

V.9 Characteristics of the impact test device.

Charpy’s pendulum is characterized by:

- Its potential energy W (shock energy),
- The V speed of the pendulum knife.

The potential energy depends on the mass of the pendulum and its height.

The energy absorbed is obtained by comparing the difference in potential energy between the start of the pendulum and the end of the test (figure 9).

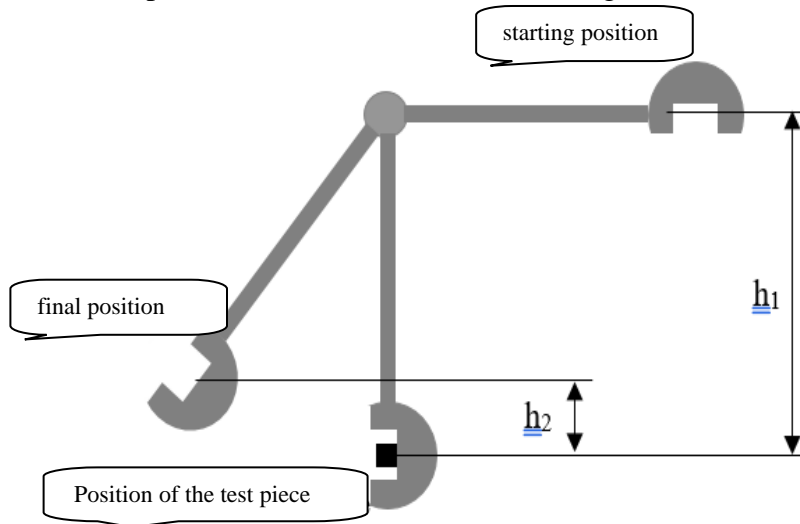


Figure. 9 Representation of the pendulum shear and the heights to be taken into account for the calculation of the energy absorbed by the rupture of the specimen.

The energy obtained (by neglecting friction) is equal to:

$$W = m.g.h_1 - m.g.h_2 \quad [N.m]$$

m: weight of the pendulum sheep (kg)

g: acceleration of gravity (about 9.81 m/s²)

h₁: height of the pendulum sheep at its starting position (m)

h₂: height of the pendulum sheep at its target position (m)

On the pendulum sheep used for this TP, the energy absorbed by the impact is obtained by direct reading using the machine's pointer.

The resilience of the notch T_n is defined by the following expression :

$$T_n = \frac{\text{"Energy absorbed" } W(J)}{\text{Section to the right of the notch}(mm^2)}$$

The shape and dimensions of the test piece used are shown in Figure 10.

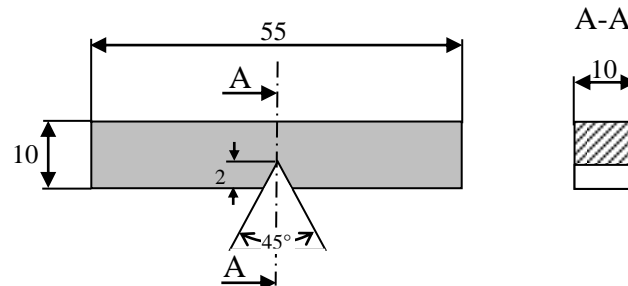


Figure 10. Geometry of the test specimen.

V.10 Conduct of the test :

- Place the test specimen on the machine as shown in Figure 6.
- Position the friction index pointer in front of the 25 N.m indication on the scale.
- Lift the pendulum to the locking position.
- Release the pendulum with the release lever.
- Stop the pendulum using the brake
- Read the pointer indication on the scale (in Joule).

Note:

Handling the device is dangerous. In fact, it involves raising the hammer (mass containing a knife) to a certain height. Then, we place the specimen at the lowest level of the hammer passage (be careful to lock the safety to fix the mass). Then we can release the mass.

The knife, in its course, will hit the test tube and break it, losing some of its energy. The energy absorbed by the test piece is equal to the energy loss of the hammer, and therefore to its potential energy loss.

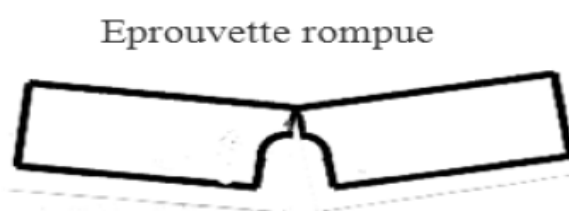
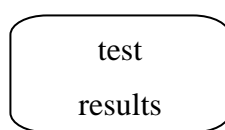
Once released from its locking position, the pendulum descends in a rotational motion around the axis. All the potential energy is thus transformed into kinetic energy at the lowest point of the trajectory where the pendulum knife collides with the test specimen causing its rupture. The energy absorbed by the shock being lower than that acquired by its movement, the pendulum continues its trajectory rising until its energy is exhausted.

V.11 Work Required:

1. Define the purpose of the resilience test
2. Describe:
 - a. The development of test pieces for the resilience test
 - b. The resilience test carried out in the TP
3. Compare the results obtained experimentally with those determined theoretically using the equations generated
4. Conclusions

V.12 Résultats :

Once the test piece is broken, the knife is braked with the brake. The reading



The result indicated by the dial is 34 Joules, hence $K_{CU} = 32 \text{ J}$

-Conclusion

First of all it can be concluded that the resilience test is destructive, that is to say that the piece is destroyed. The more fragile the materials, the less resilient they will be. Even if this test is destructive, it is of great importance because it is imperative to consider the impact resistance of a material before using it in construction for example.

PRACTICAL WORK.VI :

PW. VI

Hardness test

CHAPTERS VI :WP. VI : Hardness tests

VI.1 Introduction

Mechanical tests are used to characterize the behaviour of a material. The most frequent is the hardness test, which is most often intended to estimate quickly and simply the yield strength of the material.

The hardness test is widely used on metals. It characterizes the resistance of the material to the penetration of another body harder than it self. This test measures the average contact pressure of materials when an indenter (conical, pyramidal or spherical) is pushed into a flat surface. The hardness is assessed after removal of the indenter, from the measurement of the size of the indenter's footprint, or during the test from the indentation curve which links the indentation depth to the applied load.

It is a way of characterizing the plastic behavior of a material. Hardness, from the general symbol H (from the English- hardness), is a mechanical property that expresses the strength of a material subjected to localized plastic deformation (small indentation or scratch).

It consists in defining the resistance of a surface of the sample to the penetration of a punch, for example a hardened steel ball (**Brinell hardness**) or a diamond pyramid (**Vickers hardness**). If it resists well, it is said hard, otherwise it is said soft. The hardness is measured on different scales according to the type of material considered. It is designated mainly by the letter H, from the word Hardness in English.

VI.2 PURPOSE

- Highlight the hardness test.
- Know how to use the durometer in order to reuse it during the manipulations that follow.
- Characterization of a material from the hardness test.

VI.3 Objectives

- Highlight the hardness test.
- Know how to operate and use the durometer to measure the hardness of different Materials.
- Characterise a material from the hardness test.

VI.4 Principle of the test

The hardness can be assessed by measuring a footprint left on the surface by a punch acting under the action of a known force (Brinell, Vickers and Rockwell tests) but also by a bounce height of a very hard object on the surface to be tested (Shore test for elastomers and plastics). Ces essais se distinguent essentiellement par la forme géométrique du pénétrateur (Brinell : une sphère ; Vickers : une pyramide de base quadratique, Rockwell B, Rockwell, ect.)

Tableau 1. Different hardness test methods.


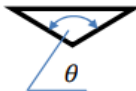

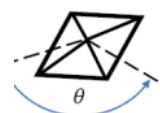
Indenter	Brinell	Rockwell		Vickers
Nature	Acier trempé ou carbure de tungstène	Diamond	hardened steel	Diamond
Forme	Sphère	Cone	Sphère	Square pyramid
Dimensions	 D=10mm ; 5mm ; 2,5 mm ; 1mm.	 $\Phi = 120^\circ$	 D=1,587mm D=3,175 mm	 $\Phi = 136^\circ$

Table. 1 All these tests have the advantage of being easier to perform and giving reproducible results. There is a wide variety of possible hardness tests, they are widely used in quality control to compare or estimate the strength or stiffness of materials.

VI.5 Test machines and test pieces

The durometers available at the RDM laboratory are of the types WOLPERT-TESTOR; Fig.1 Test pieces may be made of different metals, alloys and different square shapes, cylindrical with different radi (10, 15, 20, 25, 30 mm) having a height of at least 15 mm so that they can be held by the fingers. The surfaces of the samples must be polished and cleaned before they can be used on the durometer.

VI .6 Hardness test methods

VI.6.1 Brinell hardness (HB):

The test consists of penetrating with an F force of 3000 kgf for 15 to 30 s a penetrator having a ball shape D diameter of 10 mm, usually polished carbide, in a metal to deduce the hardness of the material.

- Mode of operation
- Place the indenter in contact with the surface of the material.
- Apply force. Hold this charge for 10 to 15 seconds.
- Measure on the print two diameters 90° apart. The measurement is carried out using a magnifying device and a graduated ruler taking into account the magnification factor. The hardness is expressed by the ratio of the load F to the surface S of the spherical calotte printed in the metal.

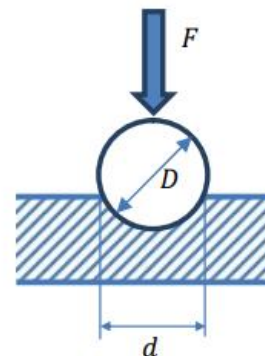
The diameter d of the footprint can be measured to within 0.05 mm by means of a strip called a Chatelier strip.



Figure.1 Hardness testing machine.

The hardness is expressed by the ratio of the load F to the surface S of the spherical calotte printed in the metal.

$$HB = \frac{F}{S} = \frac{2 \times 0,102F}{\pi D(D - \sqrt{D^2 - d^2})}$$



F: load in N.

D and **d**: diameter of the ball and the imprint (in mm).

It can be seen that the diameter **d** is larger the less hard the metal is and the deeper the ball sinks into the metal.

VI.6.2 Rockwell (HR) hardness test

The test consists of measuring in two stages the residual depth of the imprint left by a penetrant, steel ball or diamond cone, in the material to be tested by applying two loads of intensity in three stages F_0 and F_1 in three stages (F_0 , $F_0 + F_1 + F_0$).

The hardness, in this case, unlike Brinell and Vickers, is obtained by direct reading of a length of indentation from a indenter. A preload (F_0) is used to make an initial impression in order to eliminate the uncertainties inherent in surface defects.

VI.6.3 Ball test :

A hardened, polished steel ball of diameter 1.587 mm (test B or F) or 3.175 mm (test E). The ball test is not recommended if > 250 . The impression can be made on a raw surface (but free of oxidation)

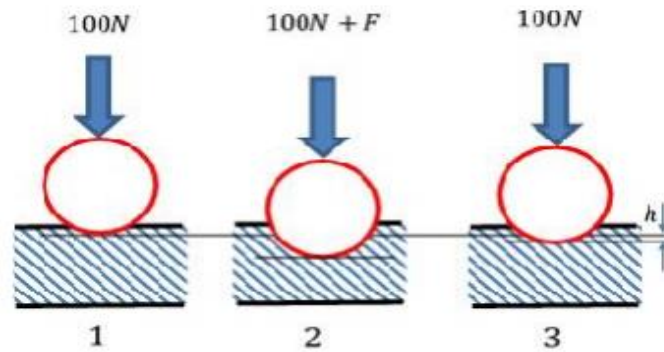


Figure 2. Rockwell test on ball.

VI.6.4 Diamond cone test

A diamond cone (Test C) of circular cross-section, 120° apex angle, with rounded spherical tip (radius 0.2 mm). The 120° top angle is used for hardness testing of hard materials > 250 . The impression must be made on a clean surface.

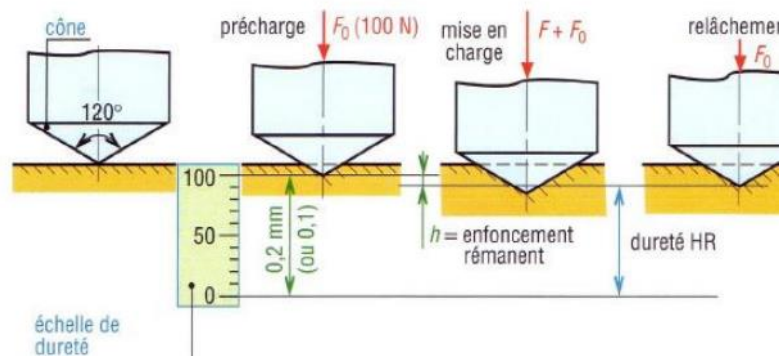
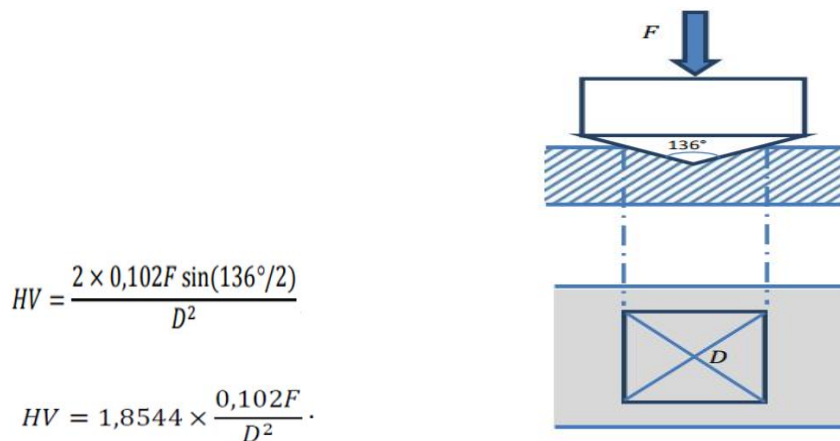


Figure 3. Essai Rockwell au cône de diamant.

VI.6.5 Vickers hardness test (HV):

The test consists of stamping a diamond indenter with a pyramid-shaped square base and an angle at the top of 136° into the metal studied, Under the action of a load F . The indenter leaves a square imprint from which the length of the diagonal (or the average of the two diagonals) can be measured with an accuracy of 0.002 mm, using a microscope attached to the machine. Vickers hardness HV is the quotient of the test load F by the area of the diagonal footprint D ;



$$HV = \frac{2 \times 0,102F \sin(136^\circ/2)}{D^2}$$

$$HV = 1,8544 \times \frac{0,102F}{D^2}$$

Figure 4. Essai Vickers

VI.7. Test Flow :

Each subgroup must have different metal samples :

Mild steel, brass, aluminum, depending on availability. First of all, it is recommended to :

- Polish the two surfaces of Each test piece ;
- Clean with alumina solution to remove burrs from surfaces ;
- If necessary, re-calibrate the durometer with the standard samples ;
- Measure for one side several measurements and take the average (limit to three measurements for this side) for each metal with both types of hardness. In order to pass a hardness test, the student must first check the accuracy of the machine by performing the hardness test on an appropriate standard sample ; that is to say, suitable for the choice of type of test (Brinell or Rockwell).

Since the type of test is chosen for the Rockwell test, the HRC hardness standard sample should be tested.

To complete this test and the following tests, students must follow these guidelines :

- Choose the corresponding load to apply.
- Turn the load control unit until you get the selected value.
- Mount the cone-shaped indenter, and place the standard sample on its holder.
- Turn the lever C to the stop, acting at the same time on both handles so as not to stress the frame. (see user manual).
- Set to zero value on the digital display following the user manual,
- Wait a few seconds (6-8 seconds) and read the hardness value on the digit,
- Repeat the same work on other places to find more values (more than 3 values),
- Calculer la valeur moyenne.

- Calculate the difference between the average value measured and the value shown on the standard sample. This difference is due to the machine error.
- In the tests which follow on the samples in question, one must take into account the error of the machine, either H is the error of the machine = $H_{\text{etalon}} - H_{\text{measured}}$ - The real hardness will therefore be equal : $H_{\text{measured}} + H$.

VI.8 Work required

- Compile these measures in a comparative table
- Interpret and discuss the results obtained and conclude

BIBLIOGRAPHICAL REFERENCES

- **AGATI, P., LEROUGE, F., & ROSSETTO, M.** (2004). Strength of materials. *Éditions Dunod*.
- **BAZERGUI, A.** (2002). Strength of materials. Presses inter Polytechnique.
- **COURBON, J.** (1988). Strength of materials. Ed. Engineerings techniques.
- **Dieter, G. E., & Bacon, D. J.** (1986). *Mechanical metallurgy* (Vol. 3). New York : McGraw-Hill.
- **L. WEBER, J.-M. DREZET**, Practical work - Materials TPI (MX2) and Metals and alloys (GM2), Polycopy EPFL, Edition 2010.
- **Mécanique de l'ingénieur, Y. B., & Tome, I. I.** (1981). Hermann.
- **Morin, M.** (1862). Strength of materials (Vol. 1). L. Hachette et Cie.
- **Norme NF EN ISO 6892**, Metallic materials — Tensile test, 2009
- **Norme NF EN ISO 148**, Metallic materials — Tensile test.
- **SPENLÉ, D., & GOURHANT, R.** (1992). Guide to calculation in Mechanics : for use by students of industrial technical education, technical and vocational high schools, university institutes of technology, section of senior technicians, auditors of training
Continuing, technicians working in companies. Technical Hatchet.
- **TIMOSHENKO, S. P.** (1968). Strength of materials. *Paris : Dunod, / c1968/1972, 1.*
http://iut.univ-lemans.fr/ydlogi/rdm_version_7.html.
<http://iut.univ-lemans.fr/ydlogi/zip/rdm7.zip>.
<http://iut.univ-lemans.fr/ydlogi/documentation.html>
- **ACHOUR A.**, Materials Resistance, Practical Work, University of Tlemcen, Faculty of Technology, Department of Civil Engineering, 1994.
- **AULNOYE L.P.**, Applied mechanics, Material strength, Shear, mechanical engineering course, IUT Civil Engineering, 2012.
- **BADEL P.**, Introduction to the Resistance of Materials, Central School of Nantes, 2012.
- **BASSET J.P., CARTRAUD P., JACQUOT C., LEROY A., PESEUX B., VAUSSY P.**, Introduction to the Resistance of Materials, Central School of Nantes, 2007.
- **AULNOYE L.P.**, Applied Mechanics, Material Strength, Shear, Course Mechanical Construction, IUT Civil Engineering, 2012.

Overview

The handout entitled : “Guided practical work The material strength 2nd Year ”presented by Dr. BOUALLEG Saïda from the Department of Civil Engineering - Université Mohamed Boudiaf de M’sila, The aim of this handout is to put into practice the various basic concepts covered in the strength of materials course. This educational document is divided into six chapters. The first deals with the tensile test, which consists in subjecting a specimen to an elongation load until failure. The second chapter studies the behavior of a concrete specimen under the influence of increasing compressive force. The third chapter enables the student to understand and appreciate the torsion of bars around their axes and the determination of the Coulomb modulus. The fourth chapter deals with simple bending by subjecting a bar to an increasing force at its center. The fifth chapter examines the ability of materials to resist impact by measuring the energy absorbed by fracture using an instrument known as the “Charpy sheep”. The sixth and final chapter of this handout studies the behavior of a material when penetrated by a harder body. The hardness test measures the average contact pressure of materials when an indenter is driven into a flat surface.

At the end of the manuscript, a bibliography is presented, including the references of the Documents used in writing this practical workbook.

Keywords :

Tensile tests, Single compression test, Torsion test, Simple Bending, Resilience test.