MATERIALS TESTING LABORATORY

FACULTY OF ENGINEERING

CHULALONGKORN UNIVERSITY

Party No. .... Date of tested ....

Name .... Graded by ....

TEST No. S6

DIRECT SHEAR TEST OF STEEL

PURPOSE	To determine the shearing stress of steel bars both in single shear and double shear.
REFERENCE	ASTM JIS
SPECIMEN	Round steel bars of different sizes and grades
APPARATUS	Shear tool with dies for different sizes of specimens

Revised by PPS @May 1998

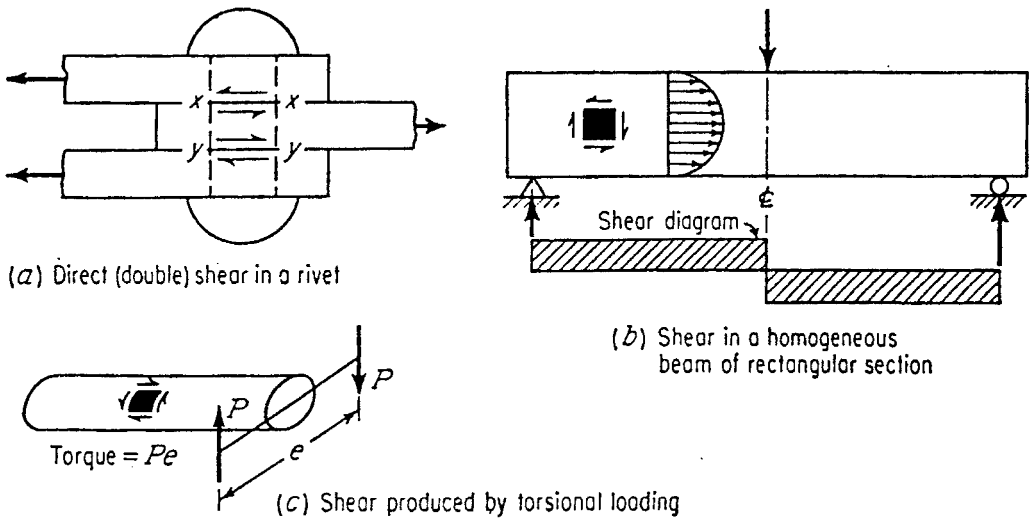
SHEARING STRESS

Shearing Stress is stress that act paralleled to a plane, as distinguished from tensile and compressive stresses that act normal to a plane. Loading that produces shear conditions of principal interest in materials testing are as follows:

a. The resultants of paralleled but opposed forces act through the center of the sections that are spaced "infinitesimal" distances apart. It is conceivable in such cases that the shearing stresses over the sections should be uniform, and a state of pure shear would exist. This condition may be approached but is never realized practically. An approximation of this condition is the case of a rivet in shear.

b. The applied opposed forces are paralleled, act normal to a longitudinal axis of the body but are spaced finite distances apart. Then in addition to the shearing stresses produced, the bending stresses are set up. In the case of a rectangular beam subjected to the transverse loads, the shearing stresses on any cross section vary in intensity from zero at the upper and lower surfaces of the beam to a maximum at the neutral axis of the beam.

c. The applied forces are paralleled and opposite but do not lie in a plane containing the longitudinal axis of the body. Here a couple is set up which produces twisting about a longitudinal axis. This twisting action on one section of a body with respect to a continuous section is termed **torsion**.



Loadings producing shear force

PROCEDURE

1. Determine the mean diameter from two readings at right angles to one another and at the section to be sheared.

2. Fix the specimen in the shear tool for testing in double shear, and apply load at a slow speed until rupture takes place. During the test note whether or nor there is a yield point.

3. Record the maximum load and the character of fracture.

4. In making a single shear test, the specimen must extend sufficiently beneath the loading tool to avoid excessive bearing stress. Likewise, in the double shear test, the specimen must overlap both dies sufficiently to avoid high bearing stresses.

DATA

Sample No.	Diameter, d (cm)	Area, A (sq. cm)	Load at Rupture, P (kg)	Shear Stress (ksc)	Remarks
<u>Nail</u> Single shear 1					
Single shear 2					
Single shear 3					
Double shear 1					
Double shear 2					
Double shear 3					
<u>Structural Steel</u> Single shear 1					
Single shear 2					
Single shear 3					
Double shear 1					
Double shear 2					
Double shear 3					

SAMPLE OF CALCULATION

Samples No. ....

Cross sectional area, A = $\frac{\pi d^2}{4}$ = ...

= .... sq. cm

Single shearing stress = P / A = ...

= .... ksc

Double shearing stress = P / (2 A) = ...

= .... ksc

SUMMARY OF RESULTS

Average single shear stress of Nail = ... ksc

Average double shear stress of Nail = ... ksc

Average single shear stress of Structural Steel = ... ksc

Average double shear stress of Structural Steel = ... ksc

DISCUSSION AND CONCLUSIONS

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TEST No. S12

TORSIONAL SHEAR TEST OF STEEL

PURPOSE To determine the behavior of the ductile steel when subjected to torsion and to obtain the following torsional properties:

1. Shearing stress at Proportional Limit by using torsion formula
2. Yield shearing stress at an offset of 0.001 radian per cm of gage length by using torsion formula
3. Shearing modulus of rupture
4. Modulus of rigidity
5. Average energy absorbed per unit volume at Proportional Limit
6. Approximate percentage of elongation at outer fiber at failure
7. Probable tensile stress at Proportional Limit

REFERENCE ASTM

JIS

SPECIMEN Round steel bars.

APPARATUS Torsion testing machine and troptometer

Revised by PPS @ May 1998

TORSION FORMULA

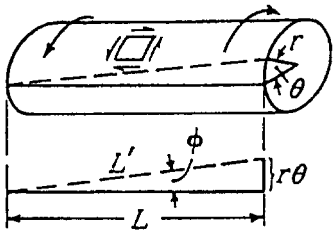


Fig. A Strain relations of twisted cylinder

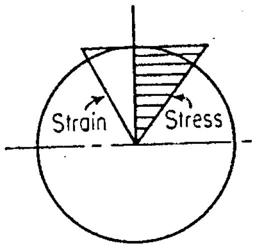


Fig. B Stress-strain variation within Proportional Limit

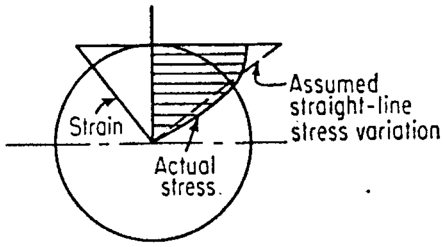


Fig. C Stress-strain variation above Proportional Limit

Various stress and strain relations for cylinder pieces in torsion are stated below in terms of the following symbols:

T is torque or torsional moment

J is the polar moment of inertia = $(\pi r^4 / 2)$ for circular section

ϕ is the shearing strain

r is the radius of a cylindrical test piece.

L is the distance between collars of the strainometer

θ is the angle of twist measured over the distance L

τ is the shearing stress in extreme fiber

E_s is the modulus of rigidity or shearing modulus of elasticity

From geometrical relations between the various elements of the circular bar subjected to torsion (see Fig. A), the shearing strain can be determined by

$$\phi = r\theta / L \tag{1}$$

Within the elastic range all evidence indicates that the shearing strains are proportional to the distance from the axis of twist. This relation appears also to hold approximately above the Proportional Limit. Within the limit of proportionality,

$$\tau = \phi E_s = (r\theta / L) E_s \tag{2}$$

The stress varies linearly from zero at the axis of twist to the maximum at the extreme fiber and varies directly with the angle of twist, (see Fig. B). By summing up the stresses over the entire cross section, the relation between shearing stress on extreme fiber and the applied torque may be found.

For the solid circular section, the maximum shearing stress is

$$\tau = T r / J = 2 T / (\pi r^3) \tag{3}$$

This relation is called the **Torsion Formula** and is applicable only to the solid circular section.

The modulus of rigidity in terms of torque and angle of twist can be expressed as

$$E_s = \tau/\phi = T L / (J \theta) = 2 T L / (\pi r^4 \theta) \tag{4}$$

It can be shown theoretically that the modulus of rigidity or shearing modulus of elasticity for homogeneous isotropic materials is about 40 percent of the modulus of elasticity in tension.

The elastic shearing stress of the ductile and the semi-ductile steels appears to be close to 0.6 of the elastic tensile stress.

The ductility in a torsion test is determined by comparing the final fiber length L' (Fig. A) at rupture with the original fiber length or gage length L. The value of the final fiber length L' is computed by knowing L, r and θ, that is

$$L' = \sqrt{L^2 + (r\theta)^2} \tag{5}$$

The **ductility** is expressed as a percentage of elongation of the outer fiber and is equal to $[(L' - L) / L] \times 100$.

PROCEDURE

1. With a micrometer screw gage, determine the mean diameter of the specimen near its mid length.

2. Note the gage length and the least reading of the troptometer. Securely clamp the instrument to the specimen, making certain that the axes of the troptometer and the test piece coincide and that the troptometer is in proper position for reading.

3. Adjust the torsion testing machine to read zero and then insert the specimen into the two ends. Check that each end is centered inside each head.

4. Gradually bring the grips in the ends to a firm equal bearing, take care not to displace the specimen. If tightening the grips produce some torque, operate the machine forward or reverse so that the torque will be reduced to zero.

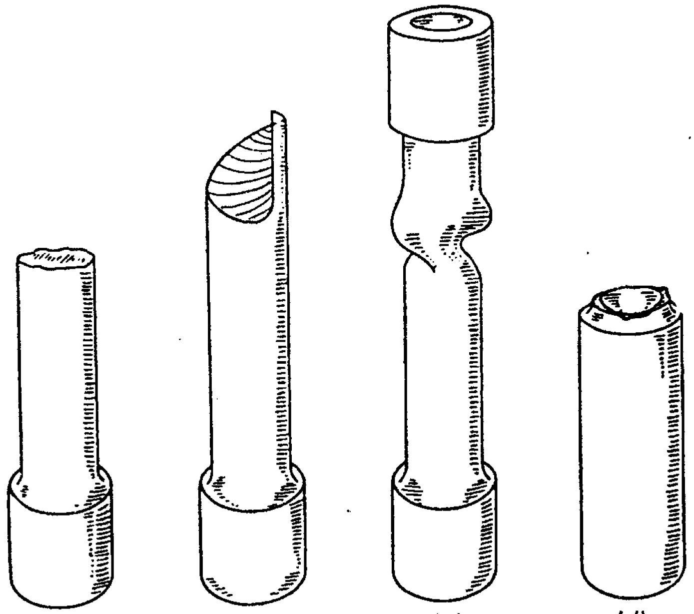
5. Remove the troptometer spacer bars and set the instrument to read zero.

6. Apply load at a slow speed. Take readings of torque and angle of twist simultaneously without stopping the machine at 300 kg-cm increments. After the specimen shows definite signs of yielding, apply the load at higher speed until failure occurs. Note the character of fracture.

7. Plot two diagrams with the same origin showing the relation between torque in kg-cm as ordinates against angle of twist or sheer strain (ϕ) in radians per cm of gage length as abscissas. One diagram will extend to the yield strength with slope of not more than 60 degrees with the strain axis. The second diagram will show the curve for the entire test.

8. Determine the torque at Proportional Limit and the yield strength at the specified offset and mark them on the first diagram.

9. Compute the quantities required.



(a) Solid bar of ductile material. Fracture on plane right section.
(b) Solid bar of brittle material. Helicoidal fracture.
(c) Tubular specimen of ductile material. Failure by buckling.
(d) Tubular specimen of ductile material; short reduced section. Failure on plane right section.

Typical failures in torsion

DATA

	Specimen No. 1	Specimen No. 2
Average radius of the bars, r (cm)	....	....
Gage length, L (cm)	....	....
Polar moment of inertia, J (cm^4)	....	....
Torque at Proportional Limit, T_{PL} (kg-cm)	....	....
Torque at an offset of 0.001 radian per cm of gage length, T_{off} (kg-cm)	....	....
Maximum torque, T_{max} (kg-cm)	....	....
Maximum angle of twist, $\theta_{max.}$ (degree)	....	....

Specimen No. 1				Specimen No. 2			
Torque (Kg-cm)	θ (Degree)	θ (Radian)	$\phi = r\theta / L$	Torque (Kg-cm)	θ (Degree)	θ(Radian)	$\phi = r\theta / L$

SAMPLE OF CALCULATION

Specimen No. ....

Shearing stress at Proportional Limit = $2 T_{PL} / (\pi r^3)$

= .... = ... ksc

Yield stress at and offset of 0.001 radian per cm of gage length

= $2 T_{off} / (\pi r^3)$

= .... = ... ksc

Shearing modulus of rupture = $2 T_{max} / (\pi r^3)$

= .... = ... ksc

Modulus of rigidity, E_s = $2 T_{PL} L / (\pi r^4 \theta_{PL})$

= .... = ... ksc

Average energy absorbed per unit volume at PL

= $\tau_{PL}^2 / (4 E_s)$

= .... = ... kg-cm/cc

Final fiber length, L' = $\sqrt{L^2 + (r \theta)^2}$

= .... = ... cm

Approximate percentage of elongation = $[(L' - L) / L] \times 100$

= .... = ... %

Probable tensile stress at Proportional Limit

= (1/0.6) x Shearing stress at Proportional Limit

= .... = ... ksc

SUMMARY OF RESULTS

	Specimen No. 1	Specimen No. 2
Shearing stress at Proportional Limit (ksc)	....	....
Yield stress at an offset of 0.001 radian per cm of gage length (ksc)	....	....
Shearing modulus of rupture (ksc)	....	....
Modulus of rigidity (ksc)	....	....
Average energy absorbed per unit volume at Proportional Limit (kg-cm/cc)	....	....
Approximate percentage of elongation at failure (%)	....	....
Probable tensile stress at Proportional Limit (ksc)	....	....

DISCUSSION AND CONCLUSIONS

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TEST No. T4

SHEAR TEST OF WOOD PARALLELLED TO THE GRAIN

PURPOSE	To determine the shearing stress of wood parallel to grain.
REFERENCE	ASTM
SPECIMEN	Standard 5 x 5 x 6.25 cm shear specimen
APPARATUS	Shear tool

SHEAR STRESS OF WOOD

Shearing stress of wood is a measure of the ability of wood to resist forces that tend to cause one part of the material to slide or slip on another part adjacent to it. The tests are made on clear, straight grained, 5 cm by 6.25 cm blocks, notched to produce failure on 5 cm by 5 cm surface. These specimens are cut so that the load is applied and the block supported on end grain surfaces. It is important that the upper surface of the projecting lip be saw exactly paralleled to the base of the block. Stress in shear perpendicular to the grain is not measured because timber would fail from other causes before maximum load could be applied.

PROCEDURE

1. Measure each specimen to 0.1 cm for the shearing dimensions and weigh to 0.1 gm. Note whether the shear is radial or tangential or some intermediate conditions, also note any defects.

2. Place the specimen in position in the shear tool. Adjust the cross bar at the rear of the tool so that **the specimen will not twist when the load is applied, its axis is vertical and the lower end tests evenly on its support.**

3. Center the shear tool in the testing machine and adjust the machine to read zero load. Bring the movable head into contact with the shearing tool at low speed; otherwise failure may occur before intended.

4. Apply the load at a speed of 6 mm per minute. Record the maximum load. Make a sketch of the ruptured specimen.

DATA AND RESULTS

Specimen No.	Shearing Area (cm x cm)	Max. Load (kg)	Shear Stress (ksc)	Remarks

DISCUSSION AND CONCLUSIONS