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## Document Release History

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## Module 4 - Structural Steel Fabrication

## Unit 6 - Castellated Beam

## Duration - 12 Hours

## Learning Outcome:

By the end of this unit each apprentice will be able to:

- Read and interpret drawing
- Fabricate a castellated beam with stiffners and end plates
- Describe the functions of a castellated beam in industry
- State the advantages and disadvantages of their use
- Describe other forms of structural sections other then conventional beams, e.g. Multi fabs

Key Learning Points:

| M Rk M | Marking out - cutting - assembly - welding. (For more information see Module 2 Unit 1 and Module 3 Unit 4). |
| :---: | :---: |
| M | Geometry - mensuration/volumes and areas. |
| Rk | Advantages of using castellated beams. |
| M Rk | Depth of finished castellated beam against the original universal beam depth. |
| M Sc Rk | Strength of finished castellated beam against original beam. |
| Sk Rk | Beam and stanchion splicing strengths, weakness and uses. <br> (For more information see Module 4 Unit 4). |
| Rk | Reasons for use of gusset plates and stiffners in structural sections. <br> (For more information see Module 4 Unit 4). |
| H | Workshop lifting with overhead gantry and forklift -safety. <br> (For more information see Module 4 Unit 1). |
| P | Ability, initiative, teamwork and safety awareness. |

## Trade of Metal Fabrication - Phase 2

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## Training Resources:

- Classroom and lecture facilities
- Standard fabrication workshop and equipment
- P.P.E.
- Drawing equipment
- Instructor lectures and demonstrations
- Lecture notes and handouts
- Transparencies
- Materials as per drawing


## Key Learning Points Code:

$\mathrm{M}=$ Maths $\quad \mathrm{D}=$ Drawing $\quad \mathrm{RK}=$ Related Knowledge $\mathrm{Sc}=$ Science
$\mathrm{P}=$ Personal Skills $\quad \mathrm{Sk}=$ Skill $\quad \mathrm{H}=$ Hazards

## Volume

The volume of a solid, liquid or gas is a measure of the space it occupies.
The unit of volume is the cubic metre. It is the space occupied by a cube with edges 1 m as shown below.


Figure 1 - Volume

In finding the volume of a figure we need to know how many cubic units are contained in that figure. A rectangular solid is a familiar and simple figure to start with.

## Example 1

Calculate the volume in cubic metres of a room 3 m high $\times 3 \mathrm{~m}$ wide x 4 m long as shown in Figure 2.


Figure 2 - Volume Example

From the sketch one may observe that the volume is $36 \mathrm{~m}^{3}$ In general, the volume of a rectangular solid is the product of its length, width and height.

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## Volume and Surface Area - Prisms

A Prism is a solid object which has exactly the same cross-section throughout its length. Thus a triangular prism, shown in Figure 3, is a solid object with a triangular crosssection throughout its length.


Figure 3 - Prisms

## Example 2

Determine the cross-sectional area and the volume of the prism shown above.

Cross-Sectional Area $=$ Area of Triangle $=3 \times 4 / 2=6 \mathrm{~m}^{2}$

Volume

$$
=6 \times 7=42 \mathrm{~m}^{3}
$$

## Surface Area of Cylinder

A cylinder is a prism with a circular base. Figure 4 shows a sketch of a cylinder of diameter 0.4 m and a height of 1.2 m . The surface area around the side of the cylinder is known as the curved surface area. If a sheet of paper was cut until it fit exactly around the curved surface of the cylinder, it would be found that the paper would be rectangular in shape as shown.


Figure 4 - Surface Area of Cylinder

Curved surface area $=\pi \mathrm{dh}$

$$
=3.14 \times 0.4 \times 1.2=1.5 \mathrm{~m}^{2}
$$

## Volume of Cylinder

The volume of a cylinder may be found by multiplying the cross-sectional area of the cylinder by its length.

## Example

Find the volume of the cylinder shown in Figure 4 above.
Cross-Sectional Area $=\pi r^{2}=3.14 \times 0.2 \times 0.2=0.1256 \mathrm{~m}^{2}$
Volume $\quad=$ Cross-Sectional Area x Length $\quad=0.1256 \times 1.2=0.15 \mathrm{~m}^{2}$
Volume of Cylinder $=\pi r^{2} \mathrm{~h}$, where $\mathrm{r}=$ radius of cylinder

$$
\mathrm{h}=\text { height of cylinder }
$$

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## Conversion between Units of Volume

There are 1000 mm in 1 metre.
One square metre contains ... $1,000 \times 1,000 \mathrm{~mm}$

$$
=1,000,000 \mathrm{~mm}^{2}
$$

One cubic metre contains ... $1,000 \times 1,000 \times 1,000 \mathrm{~mm}$

$$
=1,000,000,000 \mathrm{~mm}^{2}
$$

One billion is a very large number which is often written as $10^{9}$, the 9 represents the number of zero's after the initial 1.


Answer:
Cross-Sectional Area $=\pi \mathrm{R}^{2}-\pi \mathrm{r}^{2}$

$$
\begin{aligned}
& =3.14 \times 60 \times 60-3.14 \times 50 \times 50 \\
& =3454 \mathrm{~mm}^{2} \\
& =\text { Cross-Sectional Area } \times \text { Length } \\
& =3454 \times 1000 \\
& =3,454,000 \mathrm{~mm}^{3} \\
& =3,454,000 / 10^{9} \\
& =0.003,454 \mathrm{~m}^{3}
\end{aligned}
$$

Volume $\quad=$ Cross-Sectional Area x Length

Volume in $\mathrm{m}^{3}$

## Matter

Matter is anything which occupies space. It is divided into solid, liquid and gas.
A Solid has a definite shape, and a definite volume.


Figure 5 - Solid Matter

A Liquid flow easily. It has a definite volume but no definite shape.


Figure 6-Liquid Matter

A Gas has neither definite volume nor a definite shape. It completely fills its container. It is much lighter than the same volume of solid or liquid.


Figure 7 - Gas Matter

## Water - Solid, Liquid and Gas

If water can be solid (ice), a liquid (water) and a gas (water vapour or steam). Its state may be changed by heating or cooling.

lce slowly changes to water when put in a warm place.


When the water is heated its temperature rises and some of it changes to water vapour.


When water is boiling, bubbles appear and water vapour forms faster. It is now called steam.

## Figure 8 - Water - Solid, Liquid and Gas

When steam is cooled the opposite changes take place.


Figure 9-Cooling Steam

Another example of matter which may exist in a few states is marking dye. This dye is often sprayed on the surface of metals so that scribe lines may be clearly visible. The
marking dye is combined with a liquid gas propellant and stored in an aerosol can, as shown in the sketch below.


Figure 10 - Marking Dye

Vapour forms from some of the liquefied gas and forces the aerosol and propellant material up a standpipe in the can. When a valve on top of the can is depressed, a fine mist of droplets is produced. When the marking dye strikes the metal surface the liquid evaporates and a blue background remains.

## Mass and Weight

The mass of a body is defined as the quantity of matter in the body. The unit of mass is the kilogram usually written kg . The weight of a body is the force which the earth exerts on a body. The weight of a body varies slightly around the world. If the scale of a spring balance, as shown in Figure 11, is calibrated to read exactly 1 kilogramme when a mass of 1 kg is suspended from it in Ireland. This spring balance would read 1.002 kg at the North or South Poles whereas at the Equator the reading would be 0.997 kg .


Figure 11 - Spring Balance

To help you get used to these units. The mass of a bag of sugar is 1 kg . A man might have a mass of 60 kg . A bag of cement has a mass of 50 kg . A penny has a mass of 3 grams.
Note: There are 1,000 grams in 1 kg .

## Mass, Volume and Density

In everyday language we say, for instance, that aluminium is a light metal and that lead is a heavy one, whereas we know that equal masses of lead and aluminium would have equal weights. What we are really comparing are the mass of equal volumes. When we realise this we say that lead is more dense or, the density of lead is greater than the density of aluminium. The density of water is $1,000 \mathrm{~kg}$ per cubic metre; this means that a water tank of volume $1 \mathrm{~m}^{3}$ when full with water has a mass of $1,000 \mathrm{~kg}$ (neglecting the mass of the tank).

## Example 1

Calculate the volume and mass of water which a storage tank of length 0.8 m , width 0.4 m , and height 0.5 m would contain when completely full. Density of water is $1,000 \mathrm{~kg} / \mathrm{m}^{3}$.

$$
\begin{aligned}
& \text { Volume }=0.8 \times 0.4 \times 0.5=0.16 \mathrm{~m}^{3} \\
& \text { Mass of Water }=0.16 \times 1,000=160 \mathrm{~kg}
\end{aligned}
$$

Another useful relationship is that a mass of 1 kg of water occupies a volume of 1 litre. There are 1,000 litres in 1 cubic metre.

## Test Yourself

Calculate the volume of water in a pipe of diameter 100 mm and length 1 m . Express the volume in cubic metres and litres. State the number of $\mathrm{mm}^{3}$ in 1 litre.

Answer:

$$
\begin{array}{ll}
\text { Volume } & =\pi \mathrm{r}^{2} 1 \\
& =3.14 \times 50 \times 50 \times 1000 \\
& =7,850,000 / 10^{9} \\
& =0.00785 \mathrm{~m}^{3} \\
\text { Volume in litres } & =0.00785 \times 1000 \\
& =7.85 \text { litres }
\end{array}
$$

$$
1 \text { litre }=1,000,000 \mathrm{~mm}^{3}
$$

| A list of densities of common gases, liquids and materials are shown here: | Air................................................. $1.3 \mathrm{~kg} / \mathrm{m}^{3}$ |
| :---: | :---: |
|  | Petrol ............................................. $750 \mathrm{~kg} / \mathrm{m}^{3}$ |
|  | Water .......................................... $1,000 \mathrm{~kg} / \mathrm{m}^{3}$ |
|  | Aluminium ..................................... $2,600 \mathrm{~kg} / \mathrm{m}^{3}$ |
|  | Mild Steel ...................................... $7,300 \mathrm{~kg} / \mathrm{m}^{3}$ |
|  | Cast Iron ....................................... $7,800 \mathrm{~kg} / \mathrm{m}^{3}$ |
|  | Brass .......................................... $8,200 \mathrm{~kg} / \mathrm{m}^{3}$ |
|  | Copper ........................................ $8,700 \mathrm{~kg} / \mathrm{m}^{3}$ |
|  | Lead ....................................... $11,400 \mathrm{~kg} / \mathrm{m}^{3}$ |
|  | Mercury ................................... $13,600 \mathrm{~kg} / \mathrm{m}^{3}$ |

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## Example 2

Calculate the volume and mass of a piece of mild steel $100 \mathrm{~mm} \times 120 \mathrm{~mm} \times 10 \mathrm{~mm}$.

Density of mild steel $=7,300 \mathrm{~kg} / \mathrm{m}^{3}$

Volume $\quad=100 \times 120 \times 10$
$=120,000 \mathrm{~mm}^{3}$

Volume in $\mathrm{m}^{3} \quad=120,000 / 10^{9}$

$$
=0.00012 \mathrm{~m}^{3}
$$

Remember: There are $10^{9} \mathrm{~mm}^{3}$ in $1 \mathrm{~m}^{3}$.

$$
\text { Mass } \quad \begin{array}{ll} 
& =\text { Volume } \times \text { Density } \\
& =0.00012 \times 7,300 \\
& =0.876 \mathrm{~kg}
\end{array}
$$



Answer:

$$
\begin{aligned}
& \text { Cross-Sectional Area }=\pi r^{2}-50 \times 50 \\
& =3.14 \times 50 \times 50-2,500=5,350 \mathrm{~mm}^{3} \\
& \text { Volume } \quad=\text { Cross-Sectional Area } x \text { Length } \\
& =5350 \times 500=2,675,000 \mathrm{~mm}^{3} \\
& \text { Volume in } \mathrm{m}^{3} \quad=2,675,000 / 10^{9}=0.0026 \mathrm{~m}^{3} \\
& \text { Mass } \quad=\text { Volume } \times \text { Density } \\
& =0.0026 \times 7,800=20.28 \mathrm{~kg}
\end{aligned}
$$

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## Volume of Irregular Objects

If a solid is in the form of a rectangular or cylindrical block, its dimensions can be measured and its volume calculated. In the case of a solid having an irregular shape a simple method of determining its volume is to fill a vessel A, as shown in Figure 12, with water until it overflows. The object is then immersed in the water and the amount of displaced water is collected in vessel B. The volume of water collected in vessel B is equal to the volume of the original solid.


Figure 12 - Volume of Irregular Objects

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## Self Assessment

Questions on Background Notes - Module 4.Unit 6

## No Suggested Questions and Answers.

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