Bridges in Action: Cable-Stayed Bridges

Teacher's Notes

Aims

This pack is aimed at reinforcing National Curriculum material at KS4 in Mathematics in an enjoyable, applied way. It is aimed at students who may potentially go on to study A-Level Mathematics and has been designed with 1 hour lessons in mind. Additional material is included for able students as well as suggestions for coping with weaker students.

Curriculum content

This lesson requires the use of:

- Pythagoras' theorem
- Trigonometry

Key skills:

- Group work
- Communication

Methods covered are:

- Rounding
- Scaling (scale factors)
- Areas
- Volumes
- Surface areas
- 3D shapes

Preparation

Photocopy worksheets for students (working in pairs). Half of the class can work on harp bridges, the other half on fan bridges.

Harp: Individual worksheets for calculations – Worksheet 1
Worksheets 3, 4 and 5 for each pair on card

Fan: Individual worksheets for calculations – Worksheet 2
Worksheets 5, 6 and 7 for each pair on card

Individual Extension (worksheet 8) for more able students, or homework.

Equipment required

A4 card (preferably 240 gsm)
Sellotape (preferably of 2cm width)
String
Scissors (one per student)

Timing targets

This pack is designed for a 1 hour lesson, although it contains extension material. A model lesson is outlined below to give timing guidelines:

Start	5 mins	
Presentation	5 mins	PowerPoint presentation
Calculations	10 mins	Worksheet 1 for harp, worksheet 2 for fan
Construction of model	30 mins	Worksheets 3, 4 & 5 (harp) 5, 6 & 7 (fan)
Tidy up	5 mins	
Wrap up	5 mins	Comments on accuracy and application of Maths

Worksheet 8 – Extension work

Guidance

- The first sheet contains calculations and should be done **before** the students are given the cut-out model sheets.

Points to emphasise:

- Accuracy when cutting and marking the cables is very important. When the models are finished they will be able to see that where there is inaccuracy not all the cables are taught or they had to alter some of them.
- Engineering is about working accurately but also dealing with reality.
- Maths is applied and used in everyday situations, and if applied properly gives very rewarding results.

Mixed abilities:

- The harp bridge requires more construction time than the fan bridge. Lower ability students could be given the fan worksheets to attempt.
- If timescale is going to be a problem, perhaps two lessons could be used, or the teacher could prepare some cut-outs if necessary.
- Although sticking the strings on the underside of the card improves the appearance, they could be stuck on the upper side if time is very short.
- The extension sheets are suitable for more able students and could be used for a homework activity. They do not require the bridge cut-out model to be completed.

Presentation notes

This presentation outlines the features of the two types of cable-stayed bridges and the two construction techniques. The slides give the key information in note form, so when addressing the class, the presentation can be expanded. Additional points are added below.

Slide 1 – General information

Cable-stayed bridges cannot be used for rail since vibrations are too large.
Cable costs make the bridge relatively expensive.
Only suspension bridges can span longer distances.

Slide 2 – Construction in stages

Towers are constructed simultaneously and then the deck is built out in stages, symmetrically, from each tower.
Material storage space is created as the deck is built outwards.
Construction times are quicker since work can be done simultaneously.

Slide 3 – Two-part construction

The towers are constructed first and the deck is built on land.
The deck is then pushed out towards the other end of the bridge, resting on intermediate towers. It is then secured in place.
This generally takes longer than a construction in stages.

Slide 4 – Fan

Variations in fan design can mean that even though the cables are not connected at one single point (since this is very difficult), they are connected over a very small area which gives the same visual effect.
These bridges are usually footbridges since not many cables can be used.

Slide 5 – Harp

Harp is the more typical cable-stayed bridge design.
These bridges can have varying designs e.g. curved decks or inclined towers.

Answers

Calculations:

Harp

Cable number	Length previously calculated	Length plus fastening allowance
1	$L_1^2 = 10.0^2 + 10.6^2 = 212.36\ cm^2$ $L_1 = 14.6$ cm(to 1 d.p.)	18.6 cm
2	$L_2 = 8.6 \div \cos(42.9) = 11.7$ cm	15.7 cm
3	$L_3 = 6.0 \div \sin(42.3) = 8.9$ cm	12.9 cm
4	$L_4 = 4.0 \div \cos(49.0) = 6.1$ cm	10.1 cm
5	$L_5 = 2.6 \div \sin(52.4) = 3.3$ cm	7.3 cm

Fan

Cable number	Length previously calculated	Length plus fastening allowance
1	$L_1 = 10.0 \div \sin(43.3) = 14.6$ cm	18.6 cm
2	$L_2^2 = 10.0^2 + 8.6^2 = 173.96\ cm^2$ $L_2 = 13.2$ cm(to 1 d.p.)	17.2 cm
3	$L_3 = 6.6 \div \sin(33.4) = 12.0$ cm	16.0 cm
4	$L_4 = 4.6 \div \cos(65.3) = 11.0$ cm	15.0 cm
5	$L_5 = 10.0 \div \sin(75.4) = 10.3$ cm	14.3 cm

Scaling answers

1. 0.073 x 438 = 32 m wide
2. 3650 x 0.673 = 2460 m long

Extension Answers

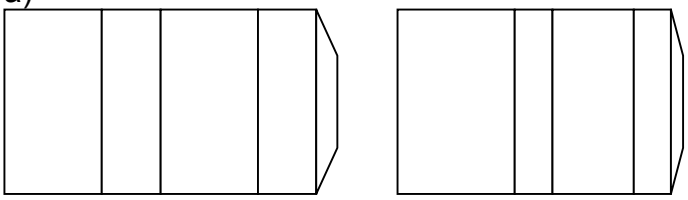
Activity 1: Areas and volumes

Shape	Calculations	Area (m^2)	Calculations	Volume (m^3)
1	8 x 0.5 x 2 + 0.5 x 0.5 x 2 or 1.5 x 0.5 x 2 + 7 x 0.5 x 2	8.5	8.5 x 15	127.5
2	(8+6) x 1.5 ÷ 2 – (7+5) x 0.5 ÷ 2	7.5	7.5 x 15	112.5
3	8 x 0.25 x 2 + 2 x 1	6.0	6.0 x 15	90.0

c) Preferred shape = shape 3

Activity 2: Nets

a)



b) It is not possible to make a net for the third shape since it is solid, not hollow.

c)

Shape	Calculations	Surface Area (m^2)
1	2x15x1.5 + 2x15x8 + 2x8.5 = 45 + 240 + 17	302
2	15x8 + 15x6 + 2x15x1.8 + 2x7.5 = 120 + 54 + 90 + 15	279
3	2x8x15 + 4x0.25x15 + 4x3x15 + 2x1x15 + 2x6 =240 + 15 + 180 + 30 + 12	477