# 611-0350 (40-500) Roman Arch
## Instructions and Applications

### Warranty and Parts:

We replace all defective or missing parts free of charge. Additional replacement parts may be ordered toll-free. We accept MasterCard, Visa, checks and School P.O.s. All products warranted to be free from defect for 90 days. Does not apply to accident, misuse or normal wear and tear. Intended for children 13 years of age and up. This item is not a toy. It may contain small parts that can be choking hazards. Adult supervision is required.

### Description:

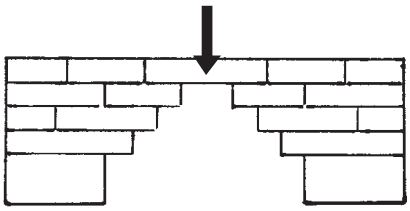
This set of 23 blocks is shaped to duplicate the construction of the Roman Arch. It gives a concrete demonstration of the action of various forces and explains why some structures are more stable than others. When correctly positioned, these blocks will support weights many times greater than that of the block set with no glue or mortar. Included is a buttress to hold the blocks in place and to provide the sideways force needed to keep the structure rigid.

### Historical Background:

The Romans did not invent the idea of the arch that bears their name. Other cultures in Africa and Asia developed the arch long before Rome's founding. The Egyptians and Greeks were aware of it although they rarely used it because their architectural style did not require horizontal forces and buttresses. The arch was limited to bridges and tombs where earth provided the needed buttress.

Use of the arch and vault in architecture stems from people to the north of Rome known as the Etruscans. They were unique at the time in their use of the arch, which was adopted by Roman architects and greatly improved.

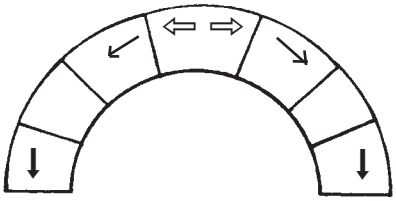
The diagrams below show three different types of arches. The **corbeled arch** (false arch) consists of layers of bricks or stones each projecting a little beyond the brick or stone beneath it until they meet at the top in a triangular pattern. The weight of the building material holds this "arch" in place regardless of whether mortar is used. All force is exerted downward.



*Corbeled Arch. Force exerts downwards.*

The **Roman Arch** (rounded arch) consists of wedge-shaped blocks cut at specific varying angles. The central block is called the *keystone* and is the essential feature.

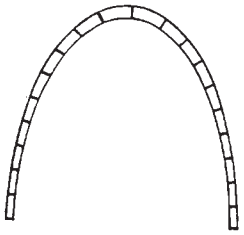
The keystone exerts force in two directions, in equal parts to the blocks on either side of it. Each subsequent block exerts force to one side, away from the keystone. The blocks are so angled that the lowest remaining block exerts force downward toward the ground. The entire structure is so stable that mortar, while often used, was not needed.



*Roman Arch*

The **Catenary Arch** is the shape that forms when you hold a piece of chain at both ends and allow it to sag into its natural shape. This type of arch permits the building of dams and vaults with thinner sections. All the horizontal force is applied at the base and the arch supports no vertical loads other than the weight of its own blocks.

This arch may be used for a roof but not a bridge due to its relative lack of strength and stability.

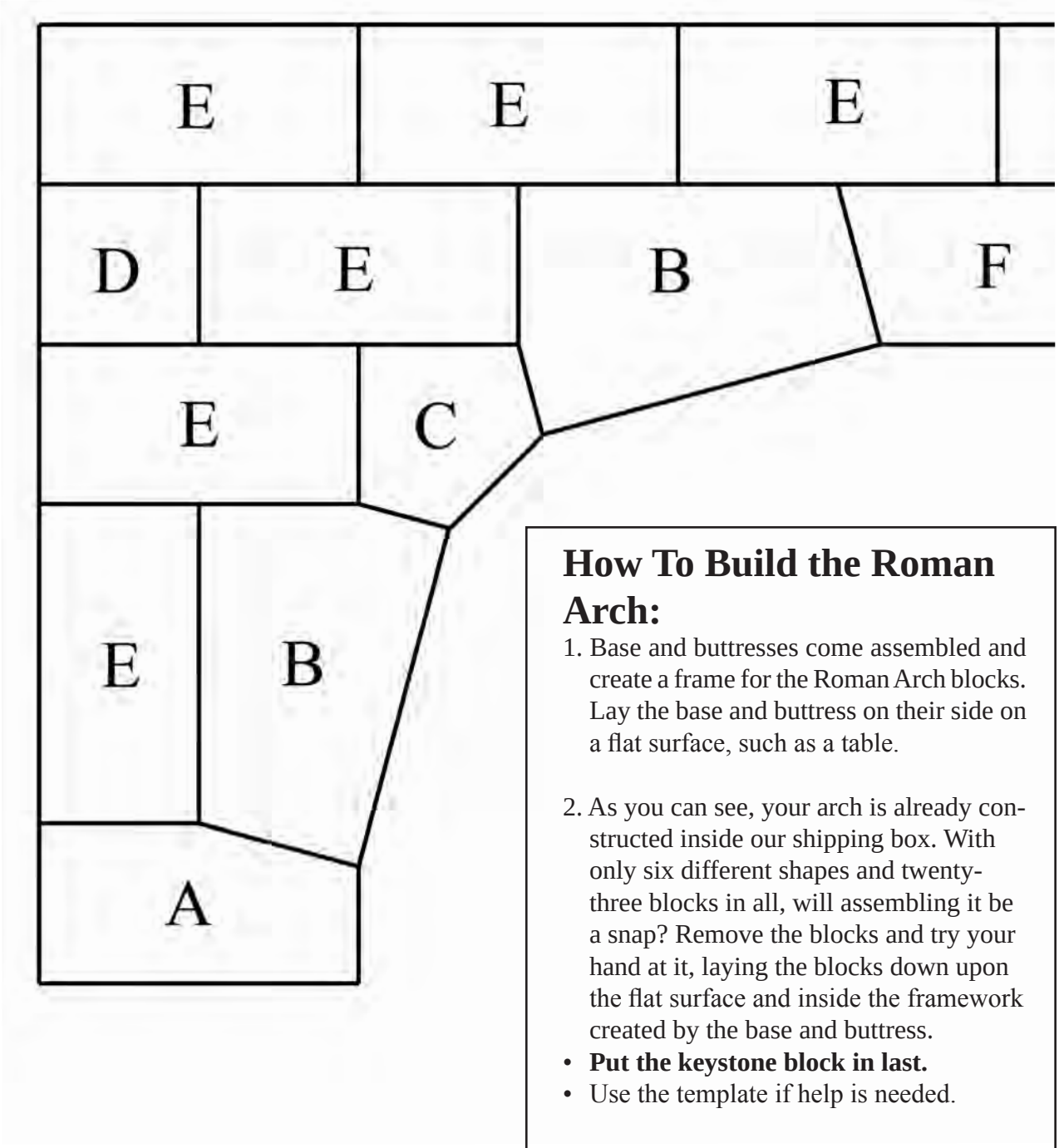


*Catenary Arch*

(Please note: **Science First®** manufactures a catenary arch block set with 13 precision blocks: 40-505. Call or check our website for more information.)

**Visit us at www.sciencefirst.com**

# Full-size template showing correct placement of blocks.



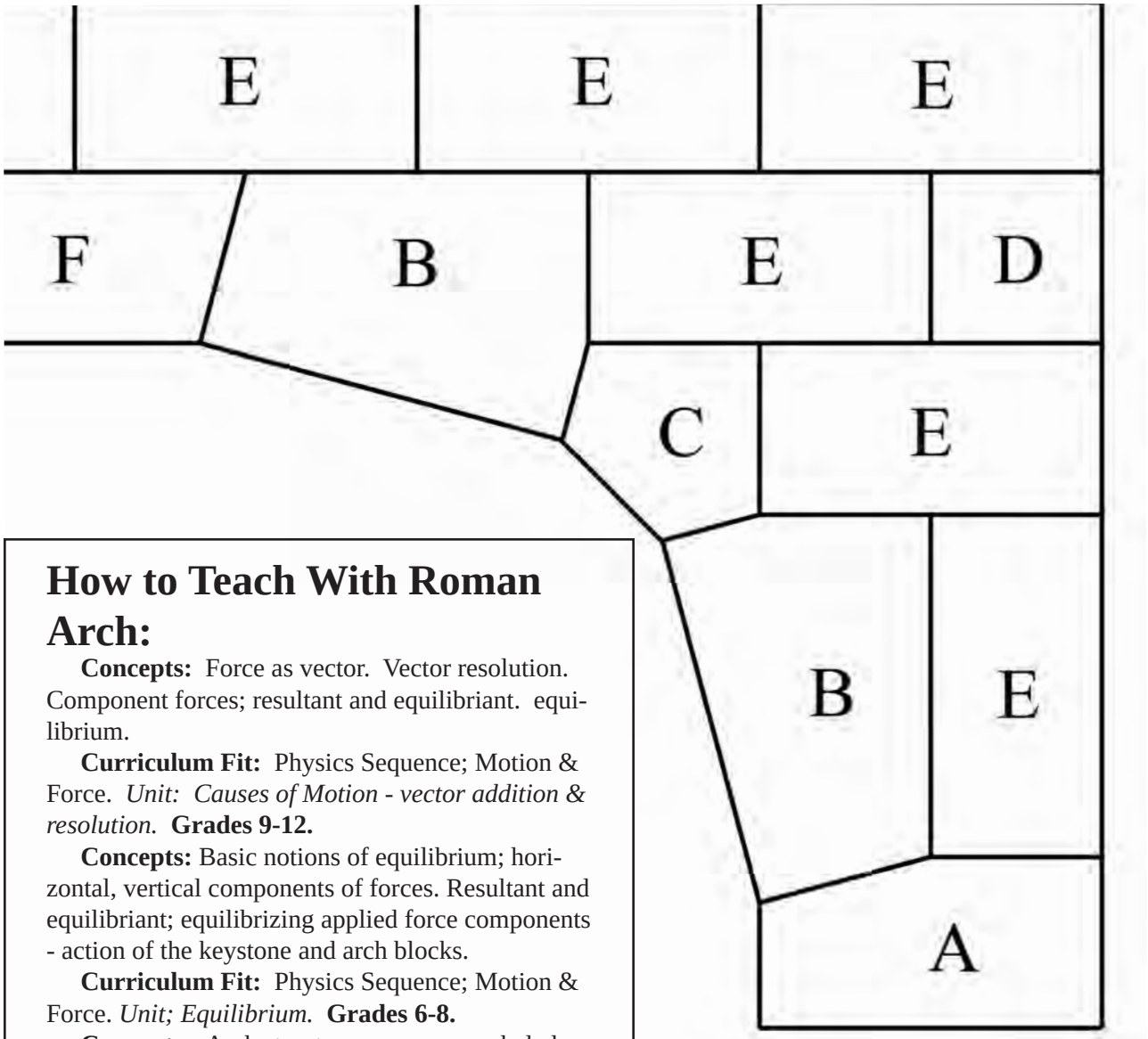

## How To Build the Roman Arch:

1. Base and buttresses come assembled and create a frame for the Roman Arch blocks. Lay the base and buttress on their side on a flat surface, such as a table.

2. As you can see, your arch is already constructed inside our shipping box. With only six different shapes and twenty-three blocks in all, will assembling it be a snap? Remove the blocks and try your hand at it, laying the blocks down upon the flat surface and inside the framework created by the base and buttress.
   - **Put the keystone block in last.**
   - Use the template if help is needed.

3. When assembled, stand the arch upright by turning the base perpendicular to table.

4. The arch is now stable enough to support your weight!




## How to Teach With Roman Arch:

**Concepts:** Force as vector. Vector resolution. Component forces; resultant and equilibriant. equilibrium.

**Curriculum Fit:** Physics Sequence; Motion & Force. *Unit: Causes of Motion - vector addition & resolution.* **Grades 9-12.**

**Concepts:** Basic notions of equilibrium; horizontal, vertical components of forces. Resultant and equilibriant; equilibrizing applied force components - action of the keystone and arch blocks.

**Curriculum Fit:** Physics Sequence; Motion & Force. *Unit; Equilibrium.* **Grades 6-8.**

**Concepts:** Arch structures - roman, corbeled, catenary.

**Curriculum Fit:** Technology/vocational preparation (building engineering) **Grades 11-12.**

## Aqueducts and Vaults:

Construction with no mortar is typified by the aqueduct in Segovia, Spain. Skill alone joins the tons of granite blocks, many of which were drilled for insertion of iron pegs to aid transportation of the blocks and to hold scaffolding in place. This aqueduct still stands and functions after 17 centuries.

The widescale construction of aqueducts, following Rome's formation of a republic, that resulted in the mastery of the freestanding arch that now bears the name. The semicircular arches used in aqueducts and bridges must be exactly half as high as its span is wide. If the span is enlarged, so must be its height. The result is that a bridge can become much higher in the center than at the two ends. The Romans built some original single-arched bridges with stairs at either end.

The original arches were just round tops to the openings in walls. It was learned, however, that arches could be used as independent units supported on piers or columns.

If an arch is prolonged on its central axis, it becomes a vault. The Romans sometimes used semicircular vaults to roof their huge public buildings. With vaulting, much larger rooms could be built with halls 80 or 90 feet wide. Two vaults could also cross at right angles and the result would remain stable. In this way, the roof over a large square area could be supported solely by piers or columns at the corners.

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## How Romans Built the Arch:

The arch could be made of stone, bricks or concrete. The Romans had a good source of concrete and liked to case the arch in this material.

To erect an arch, the builder first set up a scaffold, called centering. This scaffold had an upper surface that matched the inner surface of the arch and was used to hold up the wedge-shaped stones or bricks until they were all in place. When the centering was removed, the arch remained, held together by sideways forces. Concrete required a heavy scaffold due to the great weight of wet cement.

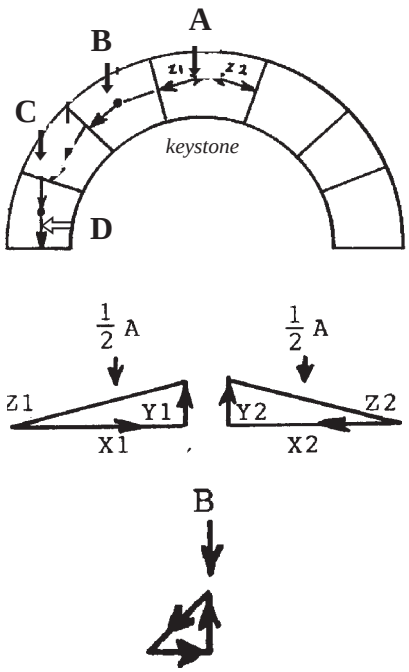
## Theory:

A vertical force applied to an arch generates a horizontal force. The diagram below depicts different forces involved in a structure of this type.

When Force **A** (defined as force at point A) is applied to *keystone* block, it produces two other forces perpendicular to the block forces Z1 and Z2. Each of these forces can be resolved into horizontal Force **X** and vertical Force **Y.** X in the diagram is four times the vertical force and is represented by line X, four times longer than line Y. A one-pound vertical force at point A, therefore, generates two pounds of horizontal force to the left and two pounds horizontal force to the right.

Force **B** generates a smaller horizontal force than A. Force **C** is smaller yet. At point **D,** Force D is zero and cannot be resolved into both vertical and horizontal components.

These horizontal forces must be resisted by equal horizontal forces applied in the opposite direction by buttresses. Otherwise the arch spreads sidewise at the base and collapses. A simple experiment will illustrate the need for horizontal support. Test the strength of the arch when all blocks are in place and again when one or two rectangular blocks are removed.




### Related Product:

**611-0355 Catenary Arch** -An ideal companion for the Roman Arch, these thirteen hardwood blocks help you understand the structural strength of a catenary arch. A catenary arch is the curve formed by a heavy, perfectly flexible cord, cable or chain hanging from two fixed points not in the same vertical line, acted on solely by gravity. While the mathematical workup may be complicated, the basic shape needn't be. Especially with a kit that doubles as a "toy" - see how fast you can assemble it *without* the full-size template!

**P/N 24-40500**