What Direction in Bridge Building?

Robert G. Bartlett

As our highly mobile nation moves into the decade of the seventies, several observations are particularly relevant. We are altering the patterns of land use for residential, commercial, and recreational facilities; sociological maturation is enabling us to achieve a closer bond in the brotherhood of men; and we are imposing more qualitative bases for decision-making in the public sector. In short, the soaring seventies will witness many changes, and it is particularly appropriate for us to challenge rather than cherish our particular fields of expertise in the disciplines of bridge design, component fabrication, and site construction. This is a time for creative stimulation that will serve as a basis for real progress. Bridge building will continue to be in great demand in the years to come, and we must be receptive to new concepts. As John Gardner stated, "If we have the wisdom and courage to demand much of ourselves—as individuals and as a profession—we may look forward to continued vitality and progress."

Is it possible to reduce bridge construction time and cost through the use of systems building concepts? Are we ready to adopt increased applications of industrialized, mass production techniques? Can we integrate planning, design, manufacture, construction, scheduling, financing, and management into a disciplined method of mechanized production of bridges?

Bridges have been important throughout history. Greeks and Romans used bridges extensively for their military conquests. Bridge building in ancient Rome was considered so important that the head of religious affairs adopted the title Pontifex Maximus or Chief Bridge Builder.

The earliest bridges were, undoubtedly, logs set across a stream. Because timber cannot endure for thousands or even hundreds of years, there are no known remaining examples of this early type of bridge construction. A notable wooden bridge resting on piles was constructed by Julius Caesar across the Rhine River in Germany in 55 B.C. A pedestrian stone-slab bridge over the River Meles in Smyrna, Asia Minor, which according to legend was used by the ancient Greek epic poet Homer, is probably the oldest bridge in existence.

The Romans used stone arches for the construction of both aqueducts and highways. Many examples of their work remain today not only in Rome but throughout what was once the vast Holy Roman Empire extending into Spain and France. The decline of the Roman Empire was followed by a period during which no new bridges of any importance were constructed for several centuries. Not until the Middle Ages, when the Crusades began, did bridge building resume to any significant extent. Stone masonry arch construction continued to be the principal type of bridge structure from the twelfth century until the eighteenth century. Although the Romans had specialized in the construction of semicircular arches, the bridges of this period varied from the pointed or Gothic arch to the flat or elliptical arch.

The Middle Ages produced a number of stone and masonry arch bridges, among them the famous London Bridge. The revival of arts, letters, and learning in Europe during the Renaissance marked the transition to a more scientific approach to bridge design and construction. Galileo, the Italian physicist, published in 1638 the first book on structural analysis. In 1678 Robert Hook devised the law of proportionality of stress and strain. After that, Mariotte and then Bernouilli in 1694 calculated deflections.

The eighteenth century marked the beginning of a new era in bridge design with the founding of the Ecole des Ponts et Chaussées in Paris, which is the first engineering school in the world. During the late eighteenth century and the first half of the nineteenth century, new materials and new bridges began to appear. The first of these new materials was cast iron, used in the construction of an arch bridge in England, and wrought iron chains, used in 1796 in the construction of the first suspension bridge in the United States at Uniontown, Pennsylvania.

The use of iron, combined with the development of the railroad, stimulated a new interest in bridge design and produced truss, cantilever, and suspension bridges. The old construction materials, wood, stone, and iron, slowly yielded to the materials of modern bridge construction, steel, concrete, aluminum, and even paper. The modern era of bridge building can be said to have begun with the development of the Bessemer process of making steel in 1855 and of the open-hearth process a few years later. The emergence of steel led to reinforced and prestressed concrete as a bridge material.

Since the end of World War II a number of technological advances in the field of bridge construction have occurred:

1. Long-span steel girder bridges were introduced, with some spans measuring more than 400 ft in length, and have largely replaced the shorter truss spans;
2. Use of welding rather than riveting in shop fabrication of plate girders has become widespread;
3. Use of high-tensile strength bolts has largely replaced field-driven rivets;
4. Prestressed concrete came into use in the middle 1950's and is now a widely accepted type of construction; and
5. Steel composite box girders and orthotropic steel decks were recently developed (the Poplar Street Bridge in St. Louis, Missouri, the first major orthotropic steel plate deck and box girder bridge built in the United States, has a center span of 600 ft).

The applications of new techniques, new materials, and equipment open new horizons in bridge construction. Significant savings in materials, labor, time, and other items of cost have been achieved through recent innovative developments, and we must continue our progress. The possibilities of more attractive structures more and more intrigue the bridge designer. The late Dr. Steinman said: "The bridge designer of this era has to be an engineer and an artist combined. To a thorough understanding of structural design and function he must add a strong feeling, both innate and trained, for beauty of form, line and proportion." However, we must combine the often-conflicting standards of aesthetics, engineering, and economy into a proper blend.

As a former highway official in Pennsylvania, and member of both the Delaware River Joint Toll Bridge Commission and Interstate Bridge Commission, I am clearly aware of the need to replace many existing outdated bridge structures, to provide new ones, and to provide safer grade separations at intersecting highways and railways.

Systems building for those bridges may be the major development of the current era. Consider the labor savings if bridges are made by the mile and sold by the foot. Systems building, however, raises some difficult questions. Where will we find the necessary supply of trained workers to produce the number of new bridges required?

Can we reduce construction time and thus reduce the time workers are exposed to relatively hazardous conditions? Can we reduce inconvenience to the public by reducing time of construction? Will we be able to achieve cost savings and thus increase the number of new structures for the same amount of tax dollars? Systems building will also require basic changes in attitudes and methods: changes in engineering standards and in manufacturing techniques, wider acceptance of new materials such as glass and paper, new developments in steel and concrete, and new methods of component transportation and site construction.