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Autor: Sluszka, Peter

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Engineer's Role in Shaping Civilization

Rôle de l'ingénieur dans l'évolution de la civilisation

Die Rolle des Ingenieurs bei der Gestaltung der Zivilisation

Peter SLUSZKA
Senior Vice Pres.
Steinman
New York, NY, USA

Peter Sluszka received his degree from Hofstra University, Uniondale, NY. He has supervised bridge rehabilitation and new bridge design projects including major structures throughout the United States. He is currently in charge of Steinman's firmwide operations.

SUMMARY

Engineers have played a vital and driving role in the evolution of civilization as we know it today. Tracing the thread from prehistoric times to the visions of the future, one becomes aware of the awesome responsibility the engineer has to his fellow man.

RESUME

Les ingénieurs ont joué un rôle essentiel et prédominant dans l'évolution de la civilisation actuelle. En parcourant l'histoire, des temps préhistoriques aux visions futures, l'on peut voir facilement la responsabilité impressionnante de l'ingénieur vis-à-vis de la société.

ZUSAMMENFASSUNG

In der Entwicklung der Zivilisation, wie wir sie heute kennen, haben Ingenieure eine lebenswichtige und treibende Rolle gespielt. Folgt man dem Faden von prähistorischen Zeiten zu den Visionen von morgen, so sieht man mit Ehrfurcht die Verantwortung des Ingenieurs gegenüber seinem Mitmenschen.

"... the bridge is more than an embodiment of the scientific knowledge of physical laws. It is equally a monument to the moral qualities of the human soul. It could never have been built by mere knowledge and scientific skill alone. It required, in addition, the infinite patience and unwearied courage by which results are achieved."

With these words, the Honorable Abram S. Hewitt, on May 24, 1883 expressed humanity's indebtedness to the builders of the Brooklyn Bridge.

If today Hewitt's words sound overly poetic and soaring, it may indeed be due to the changes in oratorical style that have occurred over the past century, but it is also due in part to our own loss of perspective and appreciation for the driving force that engineering works have been in shaping the physical world, society, and the basic human condition that we take for granted.

We have come to accept the fantastic as commonplace, the incredible feats of engineering achievement as the expected. But it was not long ago that the engineer was seen as a heroic leader of humanity, whose mission was to "subdue" the earth, as the Bible says God ordered man to do. Walt Whitman, the great American poet, expressed this thought in his lines;

> Lo, soul, seest thou not God's purpose from the first?
>
> The earth to be spann'd, connected by network,
>
> The races, neighbors, to marry and be given in marriage,
>
> The oceans to be cross'd, the distance brought near,
>
> The lands to be welded together.

What defines engineering and when did it begin? Some engineers, tongue-in-cheek, claim that it is the second oldest profession. This view may be valid if we allow latitude in the use of the term "profession." For when did we become civilized and in turn begin classifying individuals as doers of specific tasks? It was not when humans first gathered together to live in groups for the common good, because lower forms of life such as wolves, lions, even insects, preceded humans with this "societal lifestyle" (bees and ants seem to be more adept at it than we humans are, even today). It was not when humans developed the ability to communicate with each other, because again, many lower life forms do that. It can be argued very convincingly that civilization began when mankind broke free of the bounds set by its natural environment and began to shape its own world. It appears that this was an inevitable result of the physical evolution of man, as it is the human spirit, that exists for the sake of bettering itself, that has ultimately defined the species.

So we began to build. It doubtless began with primitive dwellings to deal with the weather, and primitive bridges of logs and stones connecting primitive highways cleared of brush to provide transportation to sources of food and water. It may have been very early in this evolutionary process that some individuals emerged as builders, while others were more suited for hunting, farming, etc.

As population centers grew, shortages of space and food undoubtedly led to rivalries between groups (an inherent but unfortunate characteristic of the human spirit) and defense and aggression became a more important concern of the builders. The most ancient ruins of civilized settlements generally bear one prominent feature in common, that of a system of fortifications in the form of protective walls or embankments. When man learned to protect his territory by building structures to thwart rival groups from taking what they wanted it became mutually advantageous for different societal groups to learn the concept of trade and commerce. This required transporting people and goods from one place to another and organized building of roads and bridges was born. Archaeological discoveries reveal that primitive man was remarkably industrious and creative in such civil works, even thousands of years before recorded history.

Until relatively recent times the word "engineer" had a military connotation. The empire of the Romans was based on military strength, but this strength was primarily a product of their highly developed skills in engineering. "All roads lead to Rome," the saying goes, and throughout its reign, this was literally true of the roads of the Roman Empire. In order to maintain its rule over the many settlements that were so remote from its capital, the Empire built roads and bridges, barrelling straight through from city to city to create an unhindered way for its legions of soldiers. The subjects of the Empire knew very well where the end of the road was.

But this formidable system of great roads also caused the intermingling of knowledge and cultures from the diverse peoples throughout much of the old world, and accelerated the evolution of civilization. Individual societies were no longer left to develop in isolation and mankind grew closer to becoming a singular, collective, whole. Eventually, through this exchange of knowledge more and more societies found the means and will to create important civil works for the betterment of their lives. Human intellect steadily moved toward higher ideals and philosophies and the recognition that society's reason for being is to work toward the common benefit of all.

While today we do not usually think of the engineer in terms of the governing segment of society, in ancient times the leaders were those who could direct the building of public and military works. The word "Pontiff", which today refers to the Pope of the Roman Catholic Church, originally meant "Bridge Builder," an interesting clue to the leadership role the engineer has played in history. It was recognized that society could only be sustained and improved when people did not have to struggle merely to survive. The construction of dwellings, systems to provide adequate water and sanitation, and reliable transportation routes were absolute necessities if civilization was to continue its course. The engineer was thus very powerful and influential in ancient times.

As this process of evolution continued, the human mind delved deeper into an understanding of the physical world. Science and mathematics progressed in the relentless pursuit of the technology that humanity demands, eventually leading to the industrial revolution of the 19th century. Engineering was freed from its military limitation and became a profession dedicated to building machines, structures, and highways for civilian purposes as well.

It was during this time that industrial machinery increased our ability to manufacture all nature of goods in mass quantities, making them available to a much broader segment of the population. The invention of electrical power generation and incandescent lights changed forever the way humans lived. As

the industrial and commerce centers of the world grew steadily larger, so did the concentration of people needed to keep the machinery running.

These developments are what shaped the modern cities of the world. New York, as a glowing example, became overcrowded and began to overflow its geographical boundaries. The development of taller buildings was seen as a partial answer to packing more people and more industrial space within its confines. In 1849, James Bogardus built a factory framed entirely of cast iron, the first such use of the material, although it had been known to man for thousands of years. The practical height of conventional brick, stone, and concrete buildings was five or six stories due to the massive walls and foundations that were required to bear the weight. But with the innovative use of iron, and later steel, previously unimagined heights were now possible. The invention in 1854 of Elisha Otis's "safety hoister," or safe elevator made the skyscraper not only possible, but practical as well. An increasing boldness and a spirit of rivalry drove American engineers to build even taller buildings, and by 1890 the Pulitzer Building, on Manhattan's Park Row, held the world's record at 106 meters.

These furious advances in the construction of buildings were accompanied by still other advances in engineering that illustrate the old saw that "necessity is the mother of invention." The need to supply water to the teaming population led to the construction of the Croton Reservoir and Aqueduct, itself a major engineering achievement completed in 1842. Where 70 years earlier the city's sewage was being removed by lines of slaves carrying tubs to the river, over 150 km of underground sewer pipes were doing the job by the late 1850's (today, the system totals almost 10,000 km). The need to transport the city's workers to and from their homes in nearby rural Brooklyn set the stage for John Roebling to design his masterpiece Brooklyn Bridge which, using steel wire in its cables for the first time, was the prototype for modern long-span suspension bridges.

One cannot over emphasize the importance of transportation in the proliferation of civilized society worldwide. The construction of canals, railroads, and highways, with their requisite bridges and tunnels, was a key factor in shaping today's world. It is self-evident that the exploration, settlement and industrialization of larger geographical areas depend on transporting people and things. As we observe the new order of a more unified world taking shape there are monumental transportation projects underway as the first and necessary step to make the future possible.

Great Britain and France will soon be joined by a tunnel beneath the English Channel, one of the greatest civil engineering achievements in history and a milestone of cooperation between an international alliance of engineers and builders. There are numerous bridge building projects underway in Asia and Europe that will change civilization forever. The Great Belt Link, which is now under construction will permanently unify the three major land masses of Denmark, and will be accomplished through the combined efforts of Engineers and Contractors from several European countries as well as the United States. While this project also contains one of the world's greatest tunnels, the East Bridge, with the world's longest span to date, will be yet another "monument to the moral qualities of the human soul," created by the engineer. A bridge from Denmark to Sweden is the planned next step. Japan's Honshu-Shikoku project will similarly unify its major islands. In Italy, plans are being developed to bridge the Straits of Messina, the deep and treacherous waterway that separates Sicily from the mainland. Its proposed main span of over 3,000 meters will double that of even the Great Belt Bridge.

With our steady advances in technology and physical achievements has come a heightened awareness of a not so obvious responsibility of the engineer of today and the future. We realized only recently that our machinery and construction projects have been insidiously damaging the world we inhabit, and had we chosen to ignore the evidence, we would have engineered our own destruction. We have thankfully become markedly more environmentally aware, and have begun to install checks and balances to control the impact that our creations will have on the Earth's fragile ecosystem. We have seen in some quarters a complete turnaround in our attitude toward harnessing nature. In the United States, a telling example is the changing charter of the U.S. Army Corps of Engineers. The Corps dates back to the early 1800's and is charged primarily with protecting and developing the country's inland waterways to provide for transportation and adequate water supply. To this end, it fervently proceeded with massive dredging, damming and wetlands reclamation projects. Within the past thirty or forty years we have begun to learn how important wetlands are in the ecological balance of the environment, by moderating the climate, providing natural pollution control, and supporting the life cycles of a multitude of living organisms. For what was seen as disregard of these vital natural systems, the work of the Corps came under severe criticism in the 1960's, and in 1972 the U.S. Congress, with ironic brilliance, gave the Corps responsibility for protecting all of the nation's wetlands. Taking its new responsibility in earnest, the Corps now wreaks havoc on those developers who would potentially damage estuaries and swamps.

Hopefully, we have realized in time that our technology must be used carefully lest we destroy our own Mother Earth. The depletion of the ozone layer, the spectre of global warming, disastrous nuclear power plant accidents, and the visible destruction of plant and animal life throughout the world's lands and oceans are feedbacks from the engineer's work that are now redefining the engineer's role for the future. We obviously should not stop building dams to supply water to needy humanity, or rail and highway systems that bring better living conditions to undeveloped parts of the world. We have no choice but to continue building, but we must do it with an eye toward the larger scheme of things and balance the immediate human needs with the long term needs of our partner in survival; Nature.

We will continue to envision and execute great works to improve our lives and to gradually unify the peoples of the world. The shaping of the world by major engineering works is not over by any means, as some might believe.

Developing nations are moving rapidly toward industrialization and construction of infrastructure by importing and developing technology to meet their particular needs. India, for example, already has a well developed rail system that is the envy of its neighbors, and there is a national move toward increased industrialization and export of goods that will bring in the capital needed for further development. Major public works in water supply and power generation have already begun to move the country toward improved living conditions.

It is expected that major civil engineering works will eventually take place in the independent states of the former Soviet Union, where an abundance of recognized engineering skill and advanced technology will no doubt flourish with an infusion of investment from the outside world. The vast resources of these states can be tapped once a viable transportation system has been built. Russia is already revamping its civilian communication systems to do business with the rest of the world.

There is talk of bridging the Straits of Gibraltar and connecting the Aleutian Islands with Siberia. These bold visions are typical of the human spirit's natural drive to create that has brought us this far. We are witnessing blinding advances in computer aided design technology and the development of new engineering materials. The use of plastics, fibers and ceramics that developed through the space program may yield profound advances in future structures. E-Glass and Kevlar fibers, for example, have been manufactured with a tensile strength nearly two times that of modern bridge wire, opening the possibility that we may someday build superspan suspension bridges that will dwarf even the proposed Messina crossing. Advances in concrete making have yielded compressive strengths three to four times that of conventional concrete, allowing us to design more daring and more economical structures.

We will be forever occupied in repairing, maintaining, and upgrading our existing infrastructure. Well over one billion U.S. dollars will ultimately be spent on rehabilitating New York's four East River Bridges alone. We are developing ways to extend the life of these aging structures by refurbishing suspension cables and replacing roadways with more durable materials. We are strengthening the creations of our predecessors to make them capable of meeting modern demands of traffic and economical maintenance.

Major upgradings of our transportations systems will require innovative ways to increase the capacity of existing structures. The Tagus River Bridge in Lisbon, for example, is about to be retrofitted to carry rail traffic on a new second deck, as is San Francisco's famous Golden Gate Bridge.

As engineers, we can surely take pride in our profession, and we must surely never lose sight of the awesome responsibility that civilization has assigned us. It is a responsibility to the past and to the present, but even more so to the future generations. It is a responsibility to leave them with a world that is better than the one we entered.

In The Sons of Martha, a poem of tribute to the engineering profession, Rudyard Kipling eloquently portrays the engineer's place in society. This stanza from the poem is my favorite:

They do not preach that their God will rouse them a little before the nuts work loose.

They do not teach that his pity allows them to leave their work when they damn-well choose.

As in the thronged and the lighted ways, so in the dark and the desert they stand.

Wary and watchful all their days, that their brethren's days may be long in the land.