Dear Colleagues,

Steel! The very sound of the word conjures images of strength, durability, and power. Steel seems to be going up on all sides of the Capitol Crossing Project. BR 1 braces support the tops of the concrete columns, while piles line the sides and girders span the top of the excavation that will become the new Massachusetts Avenue entrance to the highway. Meanwhile, scaffolding supports the Massachusetts Avenue Bridge so it can remain open to traffic during

New Mass. Ave. Highway Entrance

Scaffolding supporting the Mass. Ave. Bridge

construction. Reinforcing steel, the ubiquitous rebar, is being set in place by workers, where it awaits the concrete pours that will form the abutments for the F and G Street bridges, and the roof and the walls of the 2nd Street exit ramp.

Reinforcing steel for the walls alongside the F Street Bridge abutment

The walls of the 2nd Street exit ramp are actually complete and the steel beams that will support the roof over it are all in place. The exit ramp will be partially operational sometime this coming June, although 2nd Street itself will remain closed for some time. The opening of the new exit ramp will be the first operational evidence that the project is on its way to its ultimate completion.

Steel girders and precast concrete slabs now cover the west lanes at the north end of the platform and work over the north-end east lanes has begun. Those ten-inch concrete slabs supported by the girders and columns will soon be covered with a four-inch topping slab to level the surface. A third layer of concrete slab will be poured next year to create the walking surface

Girders above the 2nd Street Exit Ramp

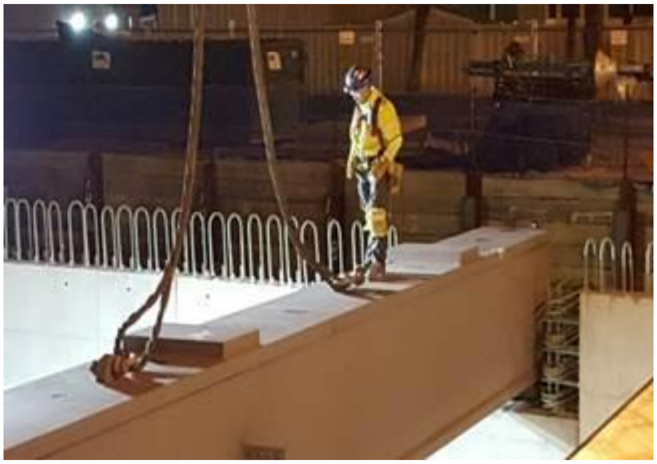
Girders and concrete slabs of the platform

inside and around the new buildings. If you are here in June, you will see a tower crane erected and construction begin on the two north buildings along Massachusetts Avenue. By November, 2016, BBC will have completed the entire platform from E Street to Massachusetts Avenue and by January, 2018, the northeast building will be completed and ready for tenants.

It is hard to imagine that this engineering marvel began only two years ago. Utilities and caissons, the bane of our existence for so many months, have disappeared from view, serving their intended purposes now and into the distant future. In a very short time, the open air highway itself will disappear from view, remembered only by those who have lived, worked, and studied in the old East End between 1966 when its construction began and November, 2016. When it is no longer visible, fifty years of misguided urban planning will be erased and the old East End will once again be united with the Downtown.

But as we watch the construction today, it is the steel girders, some relatively small and some extraordinary large, that impress and inspire awe. They arrive at night and begin an industrial theatrical event. Feel free to join me on April 21st between 9:30 and 10:00 p.m. to watch as the girders arrive -- brought to the site by drivers who back their flatbed trucks down the highway from New York Avenue. The truckers seldom deviate from a perfectly straight path for almost a mile. Once they arrive, the girders are slowly hoisted by the 300-ton Manitowoc crane and set into place --seemingly with the ease of a child placing one Lego block onto another. I sometimes wonder whether the crane operators are sculptors or magicians as they set these huge girders into concrete slots little wider than the girders themselves, slipping them

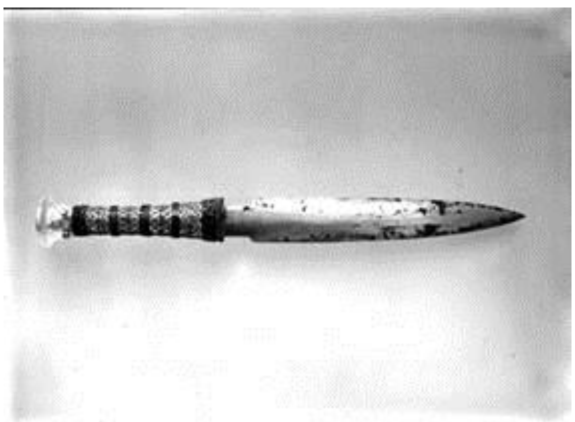
onto narrow pins that rise from the columns to hold the beams in place. Once the beams settle in, workers mount the girders and fasten the bolts that hold the girder to the column, thus ending an industrial ballet, choreographed to create the structural support for the platform.



The importance of iron and steel to the modern world cannot be denied. The oldest produced iron objects in the world date to the 4th millennium B.C.E. Ancient smiths worked pieces of almost pure meteoric iron -- that is, iron that fell to earth from the heavens. Iron production, the forerunner of steel production, began about 2000 B.C.E. and can be traced to many different areas including China, Africa, and the Middle East. However, production quickly spread throughout the inhabited world and by 1000 B.C.E., the Iron Age was well established. The ancient smiths found iron and then steel to be harder and more advantageous than bronze, an alloy that was formed from copper and tin or other metals. The earliest iron produced was known as pig iron and was similar to the wrought iron of today. The later development of cast iron began to appear in Western Europe and China around 500 B.C.E.

Iron ore is a term used for rocks with a high enough mineral iron content that it can be viably extracted by smelting. Smelting is a process whereby ore is heated to a high temperature in furnaces that are fueled by charcoal. The flow of air into the smelter, which increase the temperature of the flame, is controlled by a system of bellows. The earliest smiths were not able to produce liquid iron because the furnaces they used were incapable of reaching the high temperatures necessary to do so. According to the ENCYCLOPAEDIA BRITANNICA, "early iron was produced in small shaft furnaces as [soft but] solid lumps of iron oxide, slag, and charcoal, called blooms. The blooms were then hot forged into bars of wrought iron, a malleable material containing bits of slag, and charcoal. The carbon content of early iron ranged from very low (0.07 percent) to high (0.8 percent), the latter constituting a genuine steel."

"Smiths were different [from the rest of their community], touched by magic, blackened [by smoke and soot]." In many cultures today, smiths are still buried outside of cemeteries due to the belief that they transcend and consort with specters outside the natural realm. The iron implements the smiths produced became highly prized, so much so in Egypt that a small iron dagger was buried with King Tut in 1343 B.C.E. The Egyptians improved their production



King Tut's Iron Dagger

Iron Sickle and dagger – Han Period

process by 900 B.C.E. and were able to temper their steel to reduce its brittleness. They and others used it to produce a material that was ideally suited to the fabrication of tools, swords, and knives. There is also some evidence that the Chinese could produce heat-treated steel during the early Han dynasty (206 B.C.E. – 25 A.D.).

These early smiths almost certainly did not understand the importance of carbon in the production of steel, although they may have understood the properties that endowed their process. They also knew that if they heated their iron over charcoal fires and prayed or uttered magic incantations, sturdy objects would result. Those prayers and incantations may have measured the proper time to heat the iron to absorb the carbon from the charcoal. Whatever their theories, these ancient smiths were able to heat and then pound the metal into fine-tempered weapons and tools that were far superior to their bronze predecessors.

The Romans were prodigious users of iron weaponry. Their conquests helped spread the knowledge of pig iron production even though they also used bog iron, a form of impure iron that develops in bogs or swamps that the Romans found in the many regions they invaded. After the decline of Rome, however, centuries would pass in Europe without significant improvements to the production of steel.

Roman Infantry Gladius Sword

Roman Cavalry Spatha Sword

Iron, and its derivative, steel, are not easy to produce without high temperatures and controlled heat. Although ancient civilizations were able to extract iron from its ore and create fine weapons and tools, the process was largely misunderstood until more modern times. In the 15th century, smiths began to use waterpower with large bellows to blow air into the furnaces, thereby increasing the temperature within. The increased heat reduced the metal to a liquid rich in carbon. The liquid iron was much easier to work than the solid iron blooms due to its fluid state. As a result, smiths were able to cast it into more complex shapes than they previously produced. The technology continued to improve for the next few hundred years, permitting furnaces to attain ever-increasing temperatures.

Crucible steel, an innovation on an older method of steel production, was invented in 1740 by Benjamin Huntsman, a clock maker who needed good quality steel for his watches and springs. Made only in Sheffield, England, at first, it was the best steel in the world at the time. The steel was made by melting down pieces of inferior steel, iron, and other ingredients in a clay melting pot called a crucible that was placed in a furnace and fired to about 1600 degrees centigrade. Once the steel was melted, the pot was pulled from the furnace and the molten steel was poured into moulds (British spelling). Huntsman's method produced high-grade steel and dramatically increased its production in Sheffield. Crucible steel ultimately turned this little Midlands town into a major industrial city that became the center of the premier steel producing region in the world.

Clay melting pots used for making crucible steel

In 1855, Henry Bessemer developed a process that would boost steel mill productivity more than any other single development in the nineteenth century. Bessemer steel was made in a huge egg-shaped container called a Bessemer converter. Once the steel liquefied, the converter was tilted and the steel was poured off into moulds. Bessemer's process ultimately led to the replacement of most of the basic oxygen-driven open-hearth furnaces. Bessemer, an English inventor, also set up his steelworks in Sheffield, England. The Bessemer process was the first inexpensive industrial process for the mass production of steel from molten pig iron prior to the development of the large open-hearth furnace (not to be confused with simple oxygen driven open-hearths).

The Bessemer converter pictured below is at the Kelham Island Museum in Sheffield, England. It is the largest one I have ever seen. It is one of only three converters left in the world. It was used by the British Steel Corporation in Workington, England, until 1975, and in 1974, produced the last Bessemer Steel made in Britain. It was brought to the Museum in 1978 as an example of the revolutionary steelmaking process that originated in Sheffield. You can see a smaller converter at Station Square along the River Walk in Pittsburgh. The one in Pittsburgh is a ten-ton converter. The one in Sheffield is much larger.

When I said huge, I meant huge.
And yes, that is me standing beneath the converter.

The large open-hearth furnace was developed by William and Friedrich Siemens in 1860. It achieved temperatures of 3,600 degrees Fahrenheit and a load capacity of 300 tons of steel. “The Siemens-Martin process complemented rather than replaced the Bessemer process. It is slower and thus easier to control. Melting and refining a charge takes several hours, … however, this was an advantage in the early 20th century as it gave plant chemists time to analyze the steel and decide how much longer to refine it.” The Siemens-Martin process also permitted the melting and refining of large amounts of scrap steel, further lowering steel production costs while recycling an otherwise troublesome waste material. While these benefits enhanced the steel industry, the work environment around an open-hearth furnace was extremely dangerous because the open flame is in close proximity to the steel workers.

In 1907, Bethlehem Steel installed a mill capable of processing giant forty-eight-inch-wide flange beams. The development of these beams, which allowed builders to employ longer spans and design simpler columns, led to a renewed interest in skyscraper and steel bridge construction at the turn of the century. Structural steel remained the primary material for skyscrapers until the 1960s when designers began to use steel/concrete composite frames.

An Open-Hearth Furnace

The ENCYCLOPAEDIA BRITANNICA defines steel as "a hard, strong, durable, and malleable alloy of iron and carbon, in which the carbon content ranges up to 2 percent." It often contains other constituents such as manganese, chromium, nickel, molybdenum, copper, tungsten, cobalt, or silicon, depending on the desired alloy properties. Today, it is the most widely used material for building the world's infrastructure. With it, one can make everything from pins to skyscrapers and from toasters to aircraft carriers. Each new invention for processing steel spurs the creation of new products and innovations to common ones. The Bessemer process, for example, not only rejuvenated interest in skyscrapers, but also revolutionized women's fashion. Until the late 1850s, women's bell-shaped skirts were supported by crinoline petticoats that were stiffened by whalebone/baleen. Due to the size of baleen, the largest skirts could only be four feet in diameter. Bessemer's innovation allowed for the low-cost production of flexible steel bands or strapping. The steel bands were then turned into hoops held together by cloth tapes, which then supported the famous huge hoop skirts of the Civil War era. Some of these hoop skirts were over eight feet wide, producing fodder for cartoonists of the day. Bessemer's process also permitted the skirts to be sold at a cost that was affordable for the general public.

Whether the product is a girder or fine jewelry, the tools required to fabricate these items are made from the same alloys as the product itself, thus suggesting a magic similar to that relied on by the early magician/fabricators. Today, our need for steel seems virtually limitless. The world's steel production in 2014 was 1,665 million tons, with a growth rate of 3.8% above 2013. Production of the next most important engineering metal, aluminum, was only about 54 million tons. The main reasons for the popularity of steel [over other metals] are its relatively low fabrication, forming, and processing costs, the abundance of its two raw materials (iron ore and scrap), and its unparalleled range of mechanical properties.

The amount of steel and size of the girders used in this project are astounding. The largest beam was recently set. It was 75 feet long and weighed 126,000 pounds. The truck that brought it had thirteen axles. About 8.5 million pounds of steel has been used to build the deck. The total weight of the platform, not including the columns and caissons that hold it up, is 35 million pounds.

Workers preparing to offload the largest girder

The modern history of steel is the history of the industrial revolution itself. The names Krupp and Siemens, Carnegie, Morgan, Bessemer, and Weir conjure visions of the massive, fiery, open-hearth furnaces of Pittsburgh, Germany, and England, of the unimaginable wealth of the steel barons, and of the dangerous and dependent lives of iron and steel workers. Today, however, steel production is cleaner, safer, and leaner, and remains on the edge of modern technology. Heavily polluting and energy wasteful open-hearth furnaces are completely a thing of the past in North America. The market share of mini-mills powered by electric arc furnaces (EAF) rather than the traditional blast furnace or the Bessemer process now accounts for over 60% of all steel made in the United States. The EAFs often remelt steel scrap into new products that can contain nearly 100% recycled content. In fact, more steel is recycled than all other materials combined, making steel the most recycled material on Earth.

EAFs also have a much smaller carbon footprint than blast furnaces which require coal-based coke for the chemical reaction needed to produce new steel from raw materials. Recent increases in the use of EAFs enable the industry to claim that it has already met national carbon reduction targets. While blast furnaces can still make a higher quality steel (such as that required for exposed panels on your car or truck), EAF steel is perfectly suited for applications such as our construction project. If you want to see how steel is made from start to finish today, you can view the process at https://www.youtube.com/watch?v=9l7JqonyoKA

In both sectors — EAF and blast furnace — technology improves so rapidly that half of today's steel grades did not exist ten years ago. But once at the construction site, the technology recedes and the human touch of the crane operators and steel walkers dominate -- connecting beam to column as they perform their timeless industrial dance against the expanding urban skyline.

Carl Sandburg, the great Chicago poet, who best captured the relationship among workers, cities, and raw materials, and amongst production and construction, wrote several poems about steel. This excerpt, from the poem, *Smoke and Steel*, captures the grit of this relationship and the dangers inherent in it. It does so as well as any I have ever read. I reread it just a few days ago after I read that a construction worker in Chicago (Sandburg's hometown) had died when a 45-ton girder slipped off its column while being removed. I dedicate this Construction Note to Vicente Santoyo who died that day and to the three other injured steel workers who were working with him.

Smoke and Steel

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A bar of steel—it is only
Smoke at the heart of it, smoke and the blood of a man.
A runner of fire ran in it, ran out, ran somewhere else,
And left—smoke and the blood of a man
And the finished steel, chilled and blue.

So fire runs in, runs out, runs somewhere else again,
And the bar of steel is a gun, a wheel, a nail, a shovel,
A rudder under the sea, a steering-gear in the sky;
And always dark in the heart and through it,
Smoke and the blood of a man.
Pittsburgh, Youngstown, Gary—they make their steel with men.

In the blood of men and the ink of chimneys
The smoke nights write their oaths:
Smoke into steel and blood into steel;
Homestead, Braddock, Birmingham, they make their steel with men.
Smoke and blood is the mix of steel.

Wally Mlyniec

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Thomas Sneeringer, the former Senior Vice President for Public Policy and General Counsel for the American Iron and Steel Institute, and who represented the American steel industry in Washington for over 20 years, contributed information regarding modern steel processes.

Rebecca Nordby, Project Executive, Balfour Beatty Construction, and Wells Turnage, Senior Project Manager, Balfour Beatty Construction, contributed information concerning the steel used in the I-395 project.

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