Russell Builds a Bridge

What Do Civil Engineers Do, Anyway?

By: Russell King, PE

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Civil Engineers are men and women that enjoy building things.
Whether they like it or not, they work in the cold and the heat, they work in the rain and snow.
They work when the contractor works, during the day or overnight.
They produce documents that record the work that was done.
This book is dedicated to those hardy souls that provide inspection during construction.

Foreword

So, you want to be a civil engineer?

According to Wikipedia, *Civil Engineering is a professional engineering discipline that deals with the design, construction, and maintenance of the physical and naturally built environment, including works like roads, bridges, canals, dams, and buildings. Civil engineering is the second-oldest engineering discipline after military engineering, and it is defined to distinguish non-military engineering from military engineering. It is traditionally broken into several sub-disciplines including architectural engineering, environmental engineering, geotechnical engineering, control engineering, structural engineering, earthquake engineering, transportation engineering, forensic engineering, municipal or urban engineering, water resources engineering, materials engineering, wastewater engineering, offshore engineering, facade engineering, quantity surveying, coastal engineering, construction surveying, and construction engineering. Civil engineering takes place in the public sector from municipal through to national governments, and in the private sector from individual homeowners through to international companies.*

The author is a retired civil engineer who spent over 40 years working on civil engineering related projects – mostly design and construction of roadways; but also some underground sewer and water installations; some transportation engineering; and some quantity, construction, and land surveying. My work was done for municipal and state governments as well as the private sector. I am a registered professional engineer, retired, with a degree in Aerospace Engineering from Iowa State University - "Yes, as a matter of fact, it is Rocket Science!"

So, you see, although you need an engineering degree, you might not need it to be in a specific discipline to become registered as a professional in that specific field. It would help, but mostly you need experience and the inherent knowledge and abilities that a qualified engineering program will provide and that you need to learn.

<u>You need the ability to think.</u> I like to say that you need to be able to picture in your mind what is behind the wall and then be able to draw it, modify it to make it do what you want it to do, and then to construct it. And, you need to be ethically honest about what you are doing and why it is important. If you messed up, you need to correct it, not blame someone or something else for it. Fix it, and move on.

If you want to be in charge, than you need to be a registered Professional Engineer. But maybe you'd be more comfortable as a non-professional – they provide extensive guidance and support on construction engineering teams. You still get to build the bridge, tunnel, airport, or other public improvement and that is the real challenge. Maybe you'd be more comfortable outside of construction - in design, finance, or government?

But remember, a reasonable knowledge of construction will make you better in all other phases of civil engineering. So, be on a construction team during your early experiences to see how the plans you prepare are actually constructed. Mess around in the mud, experience the cold of a northern mid-western winter to understand what the contractor's guys have to do, see how errors or discrepancies on the plans need to be addressed in the field and how contractors do it, learn what problems occur with paying for the additional time required to make the corrections, understand how important it is for you to think about all possibilities because they will occur in the field.

You choose what is most comfortable to you – but remember that all of your actions are important for the public improvements that are the end product of the civil engineering process.

Russell King, PE

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Introduction

Bridges have been around since the first cave man put the first log across a stream to get to the other side without getting wet. They are used to separate grades and span obstructions. Today's bridges are much more complicated than that original log and include many components to make them strong, smooth, and safe. They must be capable of carrying pedestrians, bicycles, cars, busses, trucks, trains, pipelines, and even airplanes.

This book uses detailed photographs and brief descriptions to describe the role civil engineers play in bridge construction. It will show how construction proceeded, how they helped to control the construction of it, what they tested and measured, and what components were used to make the bridges modern, safe, and structurally sound.

Guidance provided by civil engineers for bridge construction is similar for other infrastructure improvement projects:

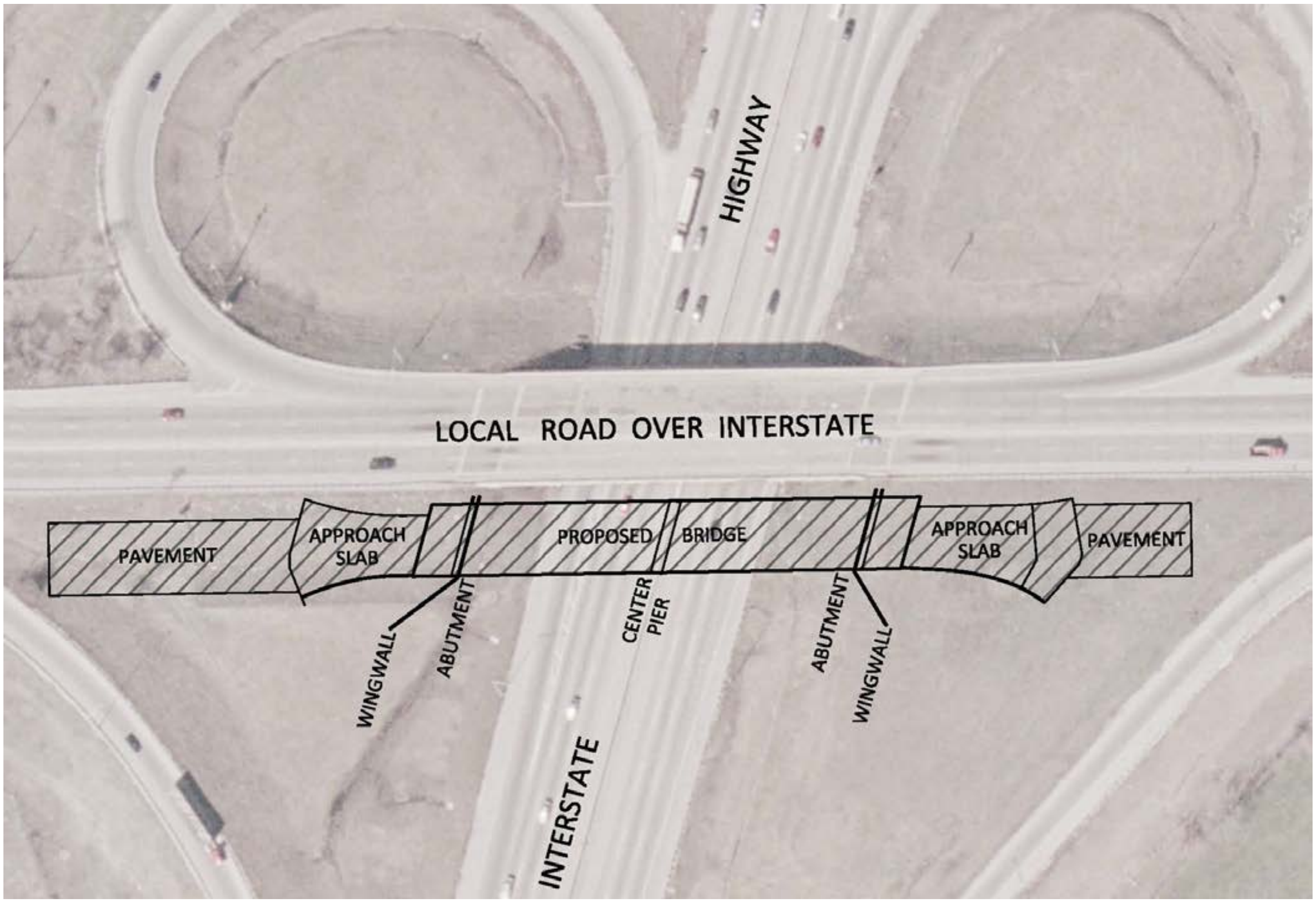
- Roads
- Buildings
- Sewers and sewage treatment plants
- Water distribution, treatment, and storage facilities
- Tunnels
- Power plants
- Underground and surface mining
- Petroleum and water wells and storage facilities
- Electric, cell, and telephone towers
- Airports.

Civil engineers play vital roles in designing, permitting, financing, and constructing every one of these projects, plus many, many, more. They work on projects that are large and small. There is, literally, a whole world of infrastructure, all around the globe, that civil engineers are involved with.

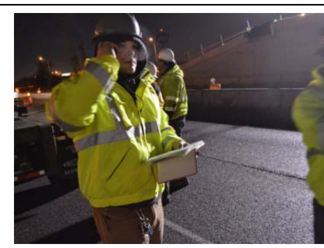
The bridges in this book are “Owned” by the public. They are typical, two-span, beam bridges with an abutment at each end, a center pier, either concrete or steel beams, and a concrete deck and wearing surface. If you will, they are "Chevrolet" bridges compared to fancy, "Cadillac" bridges, such as the Golden Gate, Verrazano-Narrows, Mackinac, or Brooklyn - the granddaddy of them all. But, just like all these fancy bridges, Russell's Bridges will carry pedestrians, cars, and trucks, and they will do it smoothly and safely. There are tens of thousands of bridges, just like Russell’s Bridges, all across the United States and a governmental agency controls, maintains, and is responsible for their safety and upkeep. Since bridge construction is expensive and complicated, the agencies usually hire outside civil engineering firms to design the bridges, contractors to construct them, and other civil engineering firms to provide construction engineering.

All of Russell’s Bridges included wing walls, an abutment at each end, a center pier, either concrete or steel beams, a deck with parapet walls and railing, and approach slabs to transition from the roadway pavement to the bridge deck. In many cases, they were new bridges constructed parallel with an existing bridge to provide additional traffic lanes to increase vehicular capacity crossing over the pavement. Once the new bridge was constructed, traffic was moved to it, the existing bridge was demolished, and a new, wider, bridge was constructed at the same location. Civil engineers studied traffic volumes, pavement geometrics, and traffic capacity to determine how many lanes were needed to safely move traffic across the bridge.

The basic bridge components for all of Russell's Bridges can be represented by a simple sketch similar to this proposed bridge. They include approach slabs, abutments, center pier, wingwalls, and concrete deck with wearing surface.





Construction Management Team

Before construction began on any of Russell's Bridges, various teams of civil engineers prepared contract documents to detail the work required for each bridge and all other improvements. Then other civil engineers employed by the owner reviewed and approved the contract documents. Once the contract documents were approved, a Construction Management (CM) Team was selected for each bridge. Each CM Team was composed of civil engineers and they:

- Inspected and documented all of the work completed by the contractor.
- Tested all of the materials used for construction and documented all of the test results.
- Acted as liaison between the contractor, the designer, and the owner for questions and issues raised during construction.
- Measured the installed quantity of all pay items. The owner approved final pay quantities, based on the measurements and calculations.
- Coordinated the day-to-day activities between construction, maintenance of traffic, ROW acquisition, erosion control, and utility relocation.
- Reviewed and recommended approval of changes to the plans due to unforeseen issues. The owner was responsible to make the final approval.
- Kept a record of all Plan changes and prepared an "As Built" set of plans to show all the changes.

For purposes of this book, the term "Civil Engineer" will be used for civil engineers educated, trained, and licensed as Professional Engineers; Construction Technologists with construction technology training and education; and Technicians or Inspectors, either with or without formal engineering education but with experience in the civil engineering field.

The CM Team was composed of the following civil engineers:

Resident Engineer (known as the "RE") -- had to be a PE:

- In day-to-day charge of all construction engineering and the CM Team.
- Assigned persons to inspect, measure, and document construction, in coordination with the contractor.
- Coordinated with the owner's project manager.
- Acted as the spokesman for the owner with the contractor, utility companies, and outside agencies.
- Coordinated lane closures between the contractor and the owner.
- Reviewed and approved pay estimates.
- Reviewed and approved shop drawings, methods of construction, questions about construction, traffic control and protection, and all related submittals.

Documentation Specialist/Assistant Resident Engineer -- should be a PE:

- Reviewed and entered reports, information, and data from the CM Team into the project management computer system.
- Checked all calculations prepared by the CM Team for accuracy, made corrections as required, and attached appropriate supporting data.
- Kept a record of the quantity of materials installed and inspected.
- Prepared pay estimates, extra work orders, and change orders.
- Kept meeting notes, prepared minutes, and sent them to participants.
- Supported the RE with contractor submittals, projected work schedule, methods of construction, and construction issues.
- Prepared daily inputs of weather, construction equipment and personnel, and work accomplished.

Material Coordinator-- could be a PE:

- Reviewed and approved material mix designs for concrete, bituminous concrete, and fill materials.
- Worked with the owner to coordinate materials from all phases and other projects on the system.
- Worked with the Quality Assurance Inspector (QA) to periodically inspect material as defined in the contract documents.
- Worked with the Quality Control Inspector (QC) to verify that all testing is being completed, as defined in the contract documents, and that all reports are completed and provided to the RE.

Technicians and Inspectors, usually were not PE's, but had training in Construction Technology:

- Measured and documented all the work completed by the contractor. Each Inspector recorded his/her observations, measurements, and project data in a field book and transferred the appropriate information to an Inspector's Daily Report (IDR).
- The Quality Assurance (QA) Inspector performed field tests for compaction, concrete, bituminous, bolt tightening, and stud shear connections and documented the results.
- Called to report lane closures, inspected them during operation, and called in when they are re-opened.
- Inspected and documented the condition of traffic control, erosion control, and maintenance of traffic.
- Received, initialed, and tabulated load tickets.

Surveyors, licensed as Professional Land Surveyor (PLS):

- Used survey equipment to verify the final position of major elements including Temporary Retaining Walls, Piles, Permanent Retaining Walls, Piers and Abutments, Beam positions, Fillets, and Finished Bridge Deck Elevation.
- Used survey equipment to continually check the furnished embankment elevation as it approached the limits.
- Used survey equipment and computer programs to measure and compute the amount of topsoil stripped and the amount of embankment furnished and compacted.

A very important CM Team function was to document quantity changes: The plans for each bridge included a detailed list of quantities required for construction. It was prepared by the designer and used by the contractor to bid the project and by the owner to prepare a budget. During construction, the CM Team measured and documented the installed quantity for all items on the lists. So, for instance, the size, shape, overlap, and weight, in pounds, of re-bars required for the center pier was calculated by the design engineer and listed on the plans. The contractor used that amount for his bid. Any deviation between the plan quantity and the installed quantity had to be justified by the contractor, submitted to and reviewed by the CM Team, and then approved by the owner. The contractor could not be paid for that pay item until the review and approval process was carried out.

What are Contract documents? Written documents that define the roles, responsibilities, and “Work” under the contract. They are legally binding on both the “Owner” and the “Contractor”. Many documents are combined to create the “Contract Documents” - Plans, Details, Special Provisions, Standard Specifications, Shop Drawings, and Contracts are a few of the more important ones. Civil engineers are heavily involved with all phases of contract document preparation and worked closely with the owner, as well as their financial, legal, and planning professionals – many of whom are also civil engineers.

What is a Professional Engineer? By definition, a Professional Engineer (PE) must have certain education and training, including:

- Graduate with at least a Bachelor of Science (BS) from an Accreditation Board for Engineering and Technology (ABET) accredited engineering school.
- Take and pass a standard Fundamentals of Engineering written exam (FE -- usually taken immediately upon graduation).
- Accumulate a minimum of four years training under the direction of Professional Engineers.
- Complete and pass a written Principles and Practice in Engineering (PE) examination.

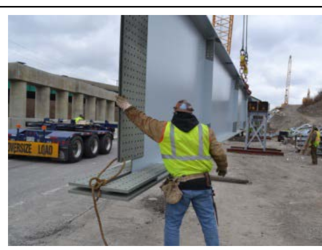
Each state has the authority and requirement to license PEs. The PE license must be renewed every two years. During the two years, the Engineer must certify that they worked on engineering projects, that they accrued professional development hours in their specialized field, and that they paid the appropriate fee.

The requirements are established and defined by states. Some states issue generic professional engineering licenses while others issue licenses for specific disciplines of engineering, such as Civil, Structural, Mechanical, Nuclear, Electrical, or Chemical. However, in all cases, engineers are ethically required to limit their practice to their area of competency. In some states, licensed civil engineers may also perform land surveys.

What are Project Management Programs? Many project owners elect to use a project management computer program to manage documents that are generated by large projects. The programs provide a structure so all persons who have an interest in the project, and are authorized to be involved, can have access to the documents. It also keeps track of the people who are required to respond to the document. All of these management programs require a CM Team member to input data daily so that the program is up-to-date and can manage the information while helping to keep important information moving.

QA and QC Inspectors: The contractor is ultimately responsible for, and must test and accept, all the materials used on the project. This requirement is well defined in the contract documents. Four tests are described in this book – for embankment, concrete, pile load, and bolts. To perform the tests, prepare the reports, and certify that the materials meet the requirements, the contractor furnishes a civil engineer to act as an inspector called the Quality Control Inspector (QC). A second inspector, provided by the CM Team and called the Quality Assurance Inspector (QA), periodically tests the same items but at a reduced rate, again, as identified in the contract documents. This cross-checking assures that the materials meet the requirements of the contract documents.

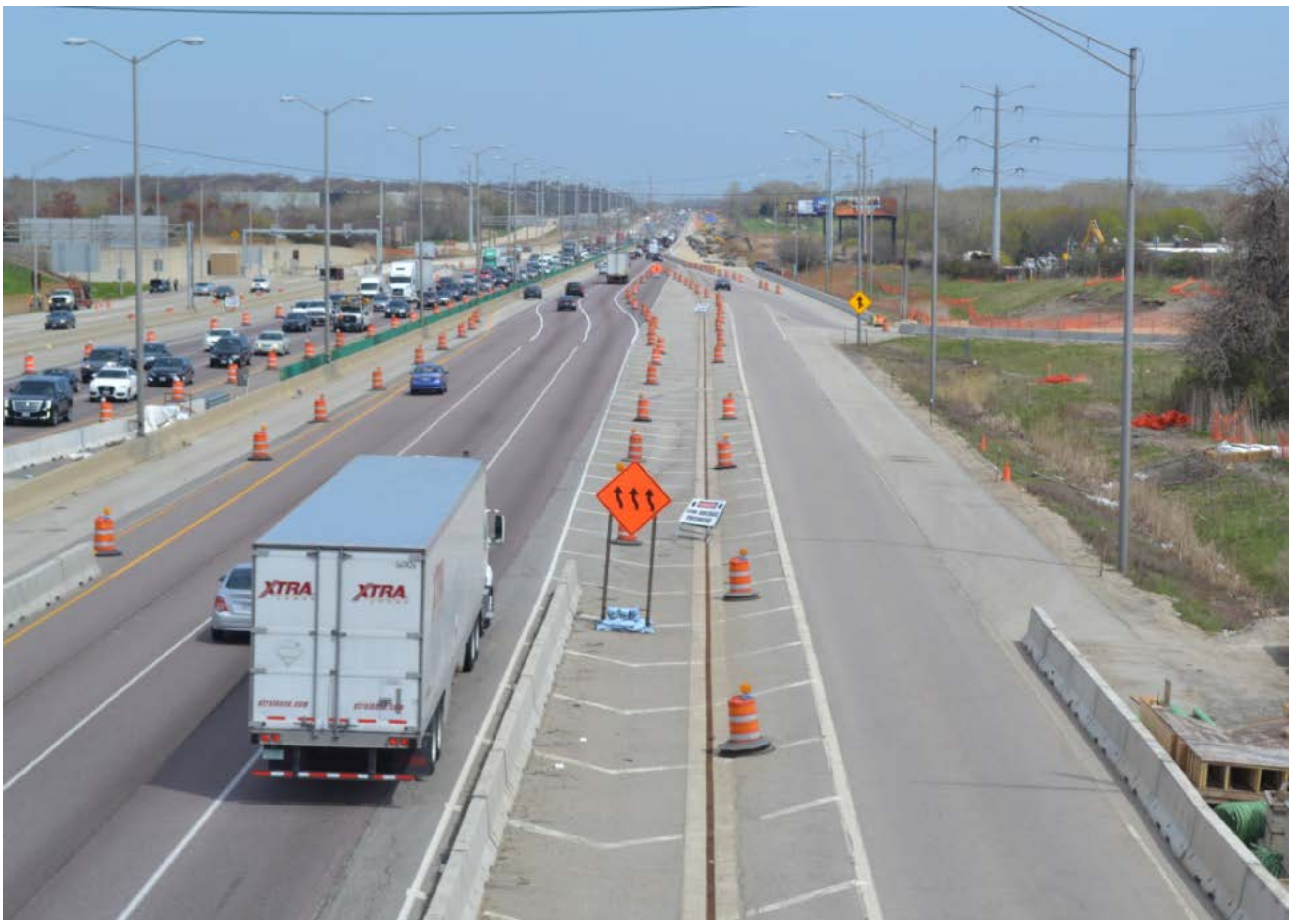
What is an Inspector's Daily Report (IDR): The IDR is a document created to consistently record certain information obtained in the field including pay items, weather, equipment, measurements, sketches, recorded information, and other observations made by the civil engineer. Additional information, such as copies of the field book pages, plan sheet details, calculations, and other supporting data are attached to the IDR, as supporting documentation, checked by the Documentation Specialist, and approved by the RE.

Maintenance of Traffic

Russell's Bridges were constructed while thousands of vehicles per day flowed freely on three lanes in each direction for the pavement being crossed plus many hundreds more on the bridge being constructed. The traffic had to be shifted to provide safe work zones. The CM Team made sure that proper weave lengths were installed, work zones were safely barricaded, and the advanced warning equipment was properly spaced.

Because there was so much traffic, well performing and properly documented traffic control was absolutely mandatory. Vehicle crashes within the construction work zone would be thoroughly investigated by all participants, including the owner, the CM Team, the contractor, and the crash victims, along with their attorneys. Proper installation of the required traffic control measures, and then inspection and documentation twice per day, once during daylight and once during the night, was required to show they were properly maintained. These reports provided vital evidence about what the conditions were like when, and if, a crash occurred.

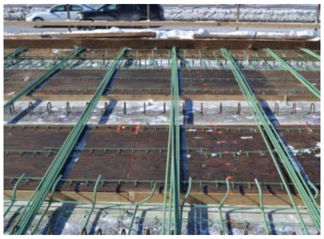


Barrels, signs, and temporary barrier walls placed to properly weave traffic around center pier construction.

Traffic control at night included lights and reflectorized boards to improve visibility.

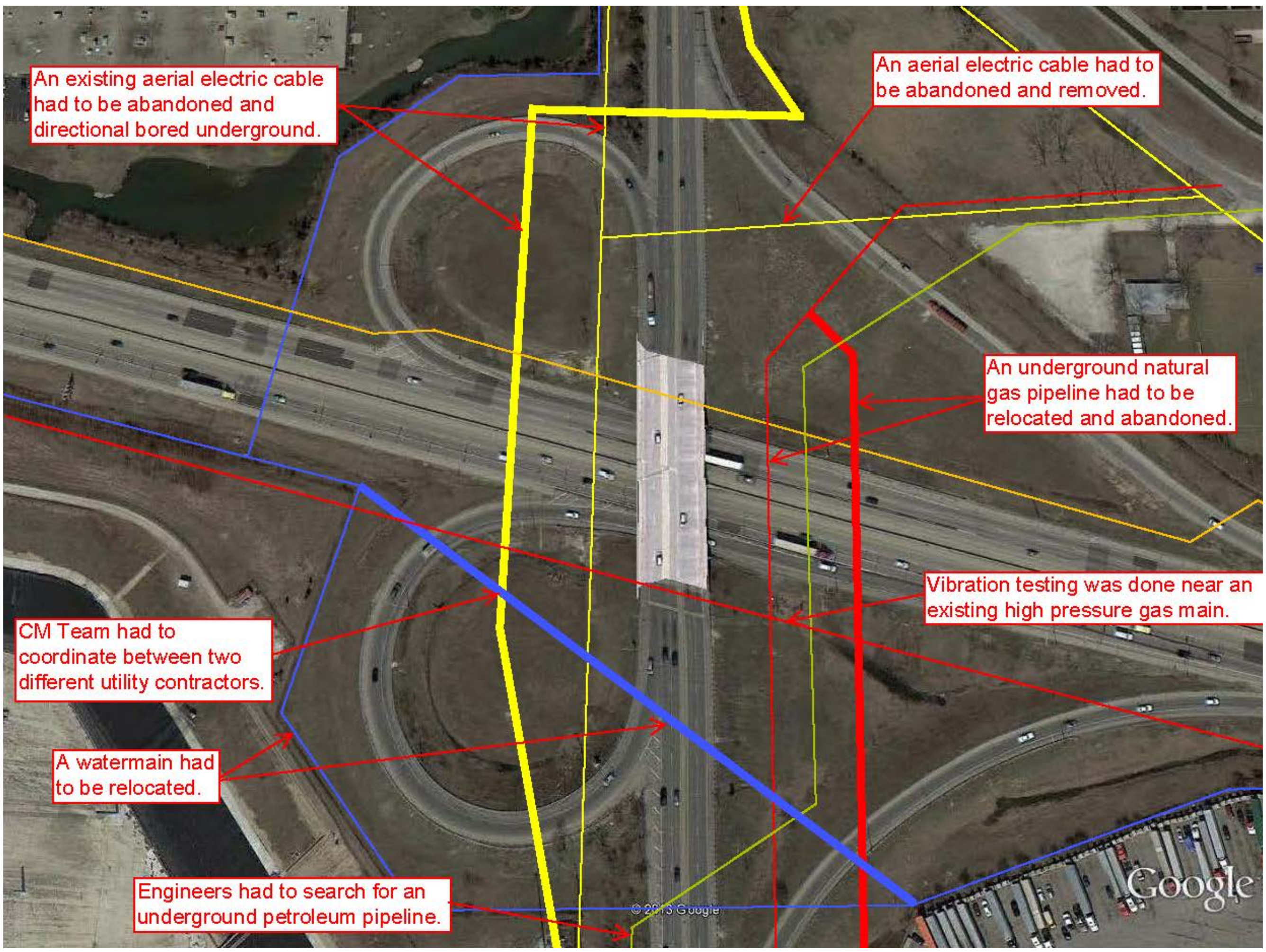
Maintenance of Traffic included searching for, recording, and repairing potholes. To do this, the CM Team inspected the pavement daily, documented its condition, and worked with the contractor to repair the potholes as they formed. In most cases, the repair work was completed overnight, between 11:00 pm and 5:00 am, in order to minimize the negative impacts on the heavy daytime traffic. There were instances, though, when a pothole developed so rapidly, and became so large, that it was an immediate safety concern. When that happened, a "Rolling Lane Closure" was approved by the owner and inspected by the CM Team. This allowed the contractor, with proper traffic control, to work in a single lane and patch the pothole(s), while traffic was passing on the remaining active lanes.

What is a Pothole? Potholes are a type of pavement failure caused by weak pavement and traffic loading. They develop randomly throughout the year, although they are generally more prevalent in late winter and early spring as freeze/thaw conditions add additional stress to the pavement structure.

Existing Utilities

Several of the bridge construction zones for Russell's Bridges included both aerial and underground utilities that needed to be relocated because they interfered with proposed bridge construction. A theoretical exhibit of utilities might include, but not be limited to, sanitary sewers, storm sewers, potable water, several different petroleum lines, aerial electric and telephone lines, fiber optic cables, and high pressure natural gas pipelines. The utility owners were required to relocate their facilities that were in conflict, so they hired civil engineering firms to prepare and submit plans for this relocation. The plans were reviewed and approved by the CM Team and the owner. The utility owners then contracted other contractors to perform the relocation. The CM Team coordinated the work and verified that they were properly relocated.



The following photographs show various engineering inspections that were performed for utility relocation. Engineers employed by the contractor were responsible to inspect and document the work as required in the contract documents. The CM Team coordinated contractors, recorded the information for the as built plans, and kept the owner informed about the work.

Gas pipeline being relocated. Engineers will test the welds prior to activating the line.
Surveyors will mark the new route and verify that it was properly relocated.
The CM Team will mark the new location on the as built plans.

Engineer testing vibrations caused by driving piles near an existing high pressure gas main.
If the vibrations became too great, the engineer would stop the pile driving.

Engineers searching for a high pressure petroleum line with a vacuum excavator.
The CM Team will mark the depth and location on the as built plans.

Water line being relocated.
Engineers will pressure test to verify no leaks and test for water purity after installation.
The CM Team will mark the new route on the as built plans.

Properly supported trench box being used to install the water pipe. Trench protection is very important to protect workers so civil engineers from government agencies inspect to verify proper protection devices.

Direct bore machine relocating underground electric cables.

Erosion Control

Erosion control is the practice of preventing or minimizing wind or water erosion on land during construction. The contract documents included a Storm Water Pollution Prevention Plan (SWPPP) which provided instructions and details to minimize erosion and non-point source pollution. The plan was prepared by civil engineers and was submitted to, and approved by, other civil engineers at the environmental protection agency. CM Team members periodically inspected the erosion control features and prepared reports to show that the features were properly installed, maintained, and were providing the necessary control.

Typical erosion control features for this type of project included silt fences, ditch checks, and temporary and permanent seeding, covered with erosion control blanket. The CM Team measured and documented all of these facilities for payment.

What is Erosion? This is a natural response to wind and/or water passing across dirt from which the ground cover was removed. When a road is under construction, the exposed dirt used for the road base, ditch section, or stockpiles can be blown or washed away.

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Silt fence and ditch checks provided erosion control by filtering runoff and collecting debris from water flowing down the ditch line.

Silt fence and ditch checks protected an existing drainage structure.

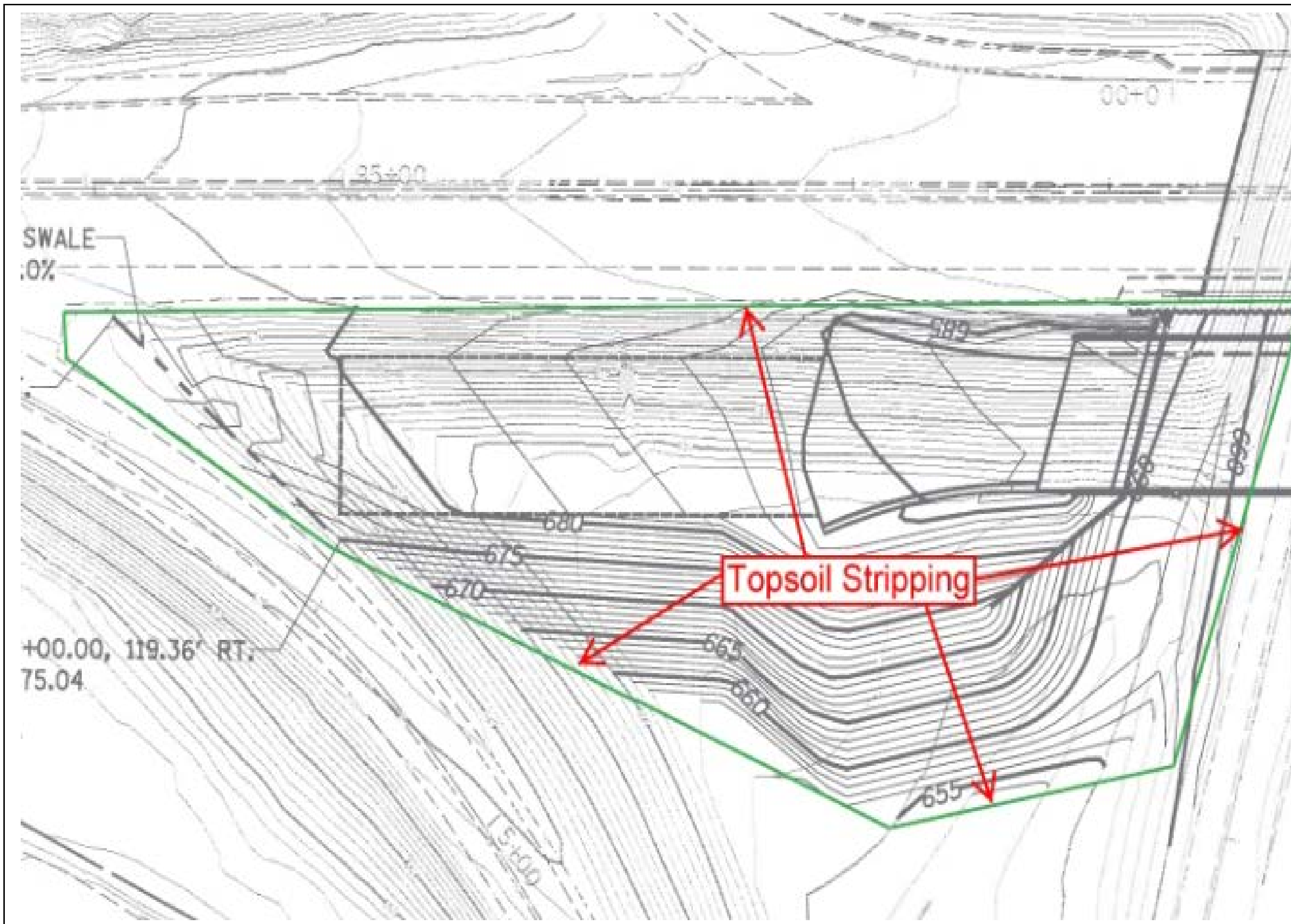
Wire reinforced fence provided extra stability to the silt fence.

Topsoil stockpile with temporary seeding and erosion control blanket.

Strip, Spread, and Stockpile Topsoil

Topsoil is material with an organic content suitable for growing crops or ground cover but not for constructing stabilized surfaces such as roadways, bridge approaches, or sidewalks. It must be removed because it is too unstable for proper compaction and its freeze/thaw characteristics allow it to expand and contract too much for pavements.

For Russell's Bridges, all the topsoil was excavated, temporarily stockpiled, and then re-spread on the embankment when it was completed. The excess topsoil was stockpiled on site and properly graded, seeded with temporary seeding, and covered with erosion control blanket to reduce erosion and improve seed germination and growth. The CM Team worked with the contractor to define topsoil limits, and measured and paid for the amount removed.



The design engineer prepared information to show where topsoil stripping was required.

This is one method to strip topsoil. Modern excavating equipment is equipped with a GPS to control the blade. Without it, surveyors must check the excavation to verify that it meets the contract documents.

Topsoil stripped and ready for final grading and compacting.
The QA and QC Inspectors will check for proper density prior to installing the aggregate base.

See how black, wet, and shiny this material is?
The QA and QC Inspectors have sampled it and determined that the material
is highly organic (i.e. Topsoil) and is not suitable as a subgrade for the proposed improvement.
It will be undercut and replaced with suitable material.

Spreading topsoil on completed embankment.

Topsoil stockpile seeded & blanketed.
The seed is fast growing to provide erosion control as soon as possible.

Seed and erosion control blanket on the finished slope.
The CM Team verified the proper slope and measured and paid for this work.

Stabilized Construction Entrance

Properly designed construction entrances were required to provide access to the construction sites. The proposed areas were properly excavated, underlain with filter fabric, and stabilized with crushed aggregate, properly placed and compacted. The entrances were then maintained during construction and removed upon completion.

Topsoil was stripped, the subgrade was properly graded and compacted, and aggregate was placed.

Stabilized construction entrance properly protected with traffic control barrels.

General civil engineering comment: Apart from providing access, construction entrances were staging areas where mud and debris on truck tires was removed. The contractor was responsible for preventing mud and debris from being deposited beyond the construction site and particularly onto adjoining public pavements. Scrapers and sweepers were continuously used to keep the adjoining surfaces clean.

Flaggers for Traffic Control

Flag persons were used to coordinate construction equipment with the motoring traffic. Properly placed and used, the flagger provides a very important advance notice to reduce conflicts with vehicles using the pavement and to prevent crashes. The flagger used a portable paddle sign and flags to alert motorists to the upcoming construction activities.

Flagger properly coordinating public traffic with construction traffic exiting onto a public road.

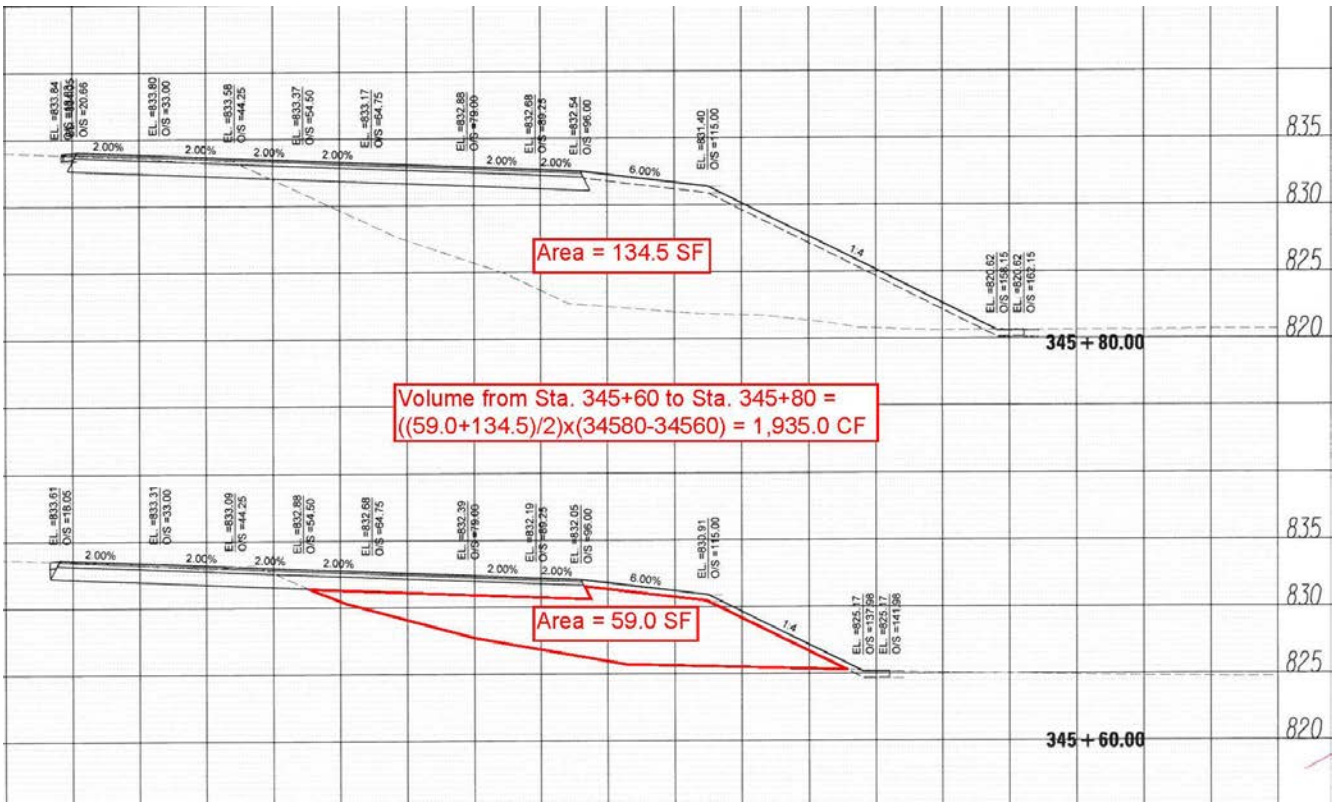
General civil engineering comment: Flagging involves knowing and understanding construction operations, vehicle movements, and potential conflicts between the construction and the vehicles. Flagger Certification is available from the American Traffic Safety Services Association (ATSSA), the National Safety Council (NSC), and the Union Laborers' & Contractors' Joint Apprenticeship Program at the state level. These certifications are available at many community colleges, through many labor unions, and other technical training agencies.

Furnished Embankment

Russell's Bridges required the contractor to furnish, place, and compact furnished embankment (FE) for fill so the approach pavement could meet the elevation of the new bridges. Cross sections in the plans were prepared by the design engineer and provided information for the contractor to estimate how much material needed to be provided. Crushed concrete, bituminous grindings, crushed aggregate, and embankment material were suitable FE as long as the gradation met the requirements of the contract documents. The FE was spread, graded in 8 inch lifts, and compacted with either a combination wheel/drum roller or sheepsfoot roller.

The following tests were performed on the FE by both the QA and QC Inspectors:

- Verified that the type of material and gradations met the contract documents.
- Verified that the lifts were placed no more than 8 inches thick.
- Verified that the material was compacted to 95% Proctor (See Testing Compaction, below).
- Accepted and signed for load tickets which verified that the proper material was delivered.
- Measured and paid for the total quantity of fill material brought and placed on site.



Cross sections were generated by the design engineer and included in the plans.
"Average End Area Method" is a typical engineering formula commonly used to calculate how much fill or excavation is required for highway alignments.
Cross sections also show the approved, finished, side slopes.

Beginning to place, grade, and compact FE.
Both QA and QC Inspectors check the density of the compacted, in place, material.

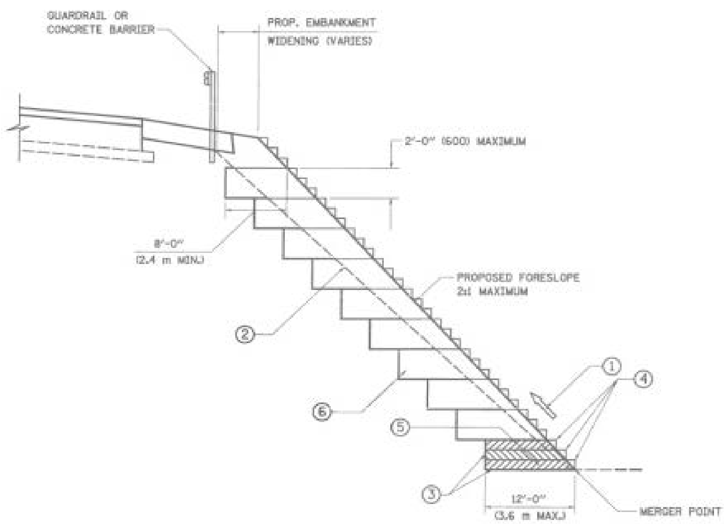
An 18 wheel semi-trailer, rear dump, can haul about 14 cu. yd. of material.
Some locations required a very small amount but some required over 15,000 cubic yards of FE.
A dozer spread the FE and a combination wheel/drum roller compacted it.

Operator and foreman review plans for correct operations.

A surveyor with GPS takes measurements to verify the embankment elevation near the final surface.

Placing Embankment along the Existing Slope

Russell's Bridges were constructed adjacent to existing, sloped embankments, up to 25 feet high. Without proper construction practices, a slip plain would develop between the existing embankment and the new fill because the two surfaces would not properly bond. This plain would cause the pavement to settle, crack, and, eventually, fail. To prevent this, benches were cut into the existing, sloped embankment to create steps to properly bond the compacted fill against the existing embankment.



TYPICAL BENCHING DETAIL
FOR EMBANKMENT

The Plan Detail shows how to excavate the benches.

Benches were cut into the existing sloped embankment to bond the furnished embankment to the existing embankment and will prevent a slip plane from forming.
The CM Team verified that the benches were cut and that the remaining material was properly compacted.

Testing Compaction

After the topsoil was stripped and the subgrade was graded and compacted, it was tested by both the QA and QC Inspectors for density and moisture content. When it passed the tests, fill material was brought to the site, placed, and compacted. Both the QA and QC Inspectors continually tested placement of the compacted material for density, moisture, and to verify that placement met the requirements of the contract documents.

The following four (4) methods are available to determine the density and moisture content:

1. Measure and weigh a sample – this method can be used on all loose materials:
   a. A sample is dug out of the compacted layer.
   b. It is dried and weighed.
   c. The volume is determined by putting a balloon in the hole and filling it with water up to the surface.
   d. The dry density, in pounds per cubic feet, is computed by dividing the weight by the volume.
2. Penetrometer – this method can be used only on subgrade because it cannot penetrate compacted course aggregates:
   a. By definition a Penetrometer is a probe used to identify the in-place density of fine grained and granular materials used for both base and subbase as well as weakly cemented materials.
   b. The probe is either pocket size or stand up length and it has an attached meter to record the density.
   c. The civil engineer pushes the probe into the material to be tested and the meter shows its approximate density.
   d. It does not measure moisture content.
3. Dynamic Cone Penetrometer (DCP) – this method can be used only on subgrade:
   a. A stand-up Penetrometer is modified to include a movable weight. It does not have a meter.
   b. The probe contains a 17.6 pound movable weight which is raised and dropped 22.6 inches to drive the probe into the material being tested.
   c. The DCP records the density more accurately than a Penetrometer by counting the number of blows required to achieve a calculated depth of penetration.
   d. Proper density is documented when the number of blows is equal to or exceeds the calculated number.
   e. It does not measure moisture content.
4. Nuclear Density Gauge – this method can be used on all loose materials:
   a. A probe is inserted into a hole approximately half way through the material being tested.
   b. A gauge emits a directed beam of atomic particles and a sensor counts the received particles reflected back from the surrounding materials.
   c. The device converts the received bounce-back particle count into material density and moisture content.
   d. The Nuclear Density Gauge is the most accurate method currently available.

Both the QA and QC Inspectors used Methods 3 & 4 to obtain field densities on the subgrade and Method 4 to obtain densities and moisture content on the furnished embankment. The density was compared with, and recorded as, a percentage of Proctor. According to the contract documents, both the subgrade and the fill had to reach a minimum 95% Proctor and the moisture content had to be a maximum of 8%.

What is Proctor? Proctor is a laboratory method of experimentally determining the optimal moisture content at which a given fill material will become most dense and achieve its maximum dry density. It must be calculated for each type of material, and must be checked often for the same type of material because the material varies and will have different characteristics. The Proctor number is computed by a civil engineer in a laboratory situation and then used by the QA and QC Inspectors in the field.

The QC Inspector using the DCP to test the subgrade after the topsoil was stripped and stockpiled.

Nuclear density gauges and equipment for both the QC and QA Inspectors.

The QC Inspector properly setting the nuclear density gauge to test and obtain the reading.

The QC Inspector, with a surveyor, locating both the horizontal and vertical position of a density reading.

The nuclear density gauge documented a density of 97.0%.

The QA Inspector recording data into the field book.
Clear notes were important because they became the original documentation for the IDR.

Temporary Soil Retention System

The existing conditions for Russell's Bridges provided a limited construction area so special practices were required to construct adequate transitions from the existing to the proposed conditions. The contract documents identified Temporary Soil Retention System (TSRS's) but, since there are several different styles of TSRS's, each contractor was required to "Design Build" the specific system they intended to use. Basic design information, such as location, height, and structural load were prepared by the design engineers and included on the plans. Enough information was supplied to allow the contractor, during the bidding process, to study and select the method they wanted to use and to allow their engineering team to prove that their system was adequate.

Soldier Piles & Lagging and Modified Structural Earth were two different methods selected at various locations by the various contractors. Soil Nail Wall, Sheet Piling, and several proprietary products were other designs they could have chosen. The following definitions apply:

1. Soldier Piles and Lagging: This method included driving steel H-piles to calculated bearing depth, excavating existing material to the wall, and installing horizontal timber members between the H-Piles as excavation proceeds.
2. Temporary Modified Structural Earth: This method included "L" shaped welded wire mesh, 18" high with a 24" leg and fabric to enclose the mesh, and tie back straps. The wire mesh baskets were stacked, covered with fabric, attached to the tie backs, and covered in 18 inch lifts with compacted select backfill.

Soldier Piles and Lagging:

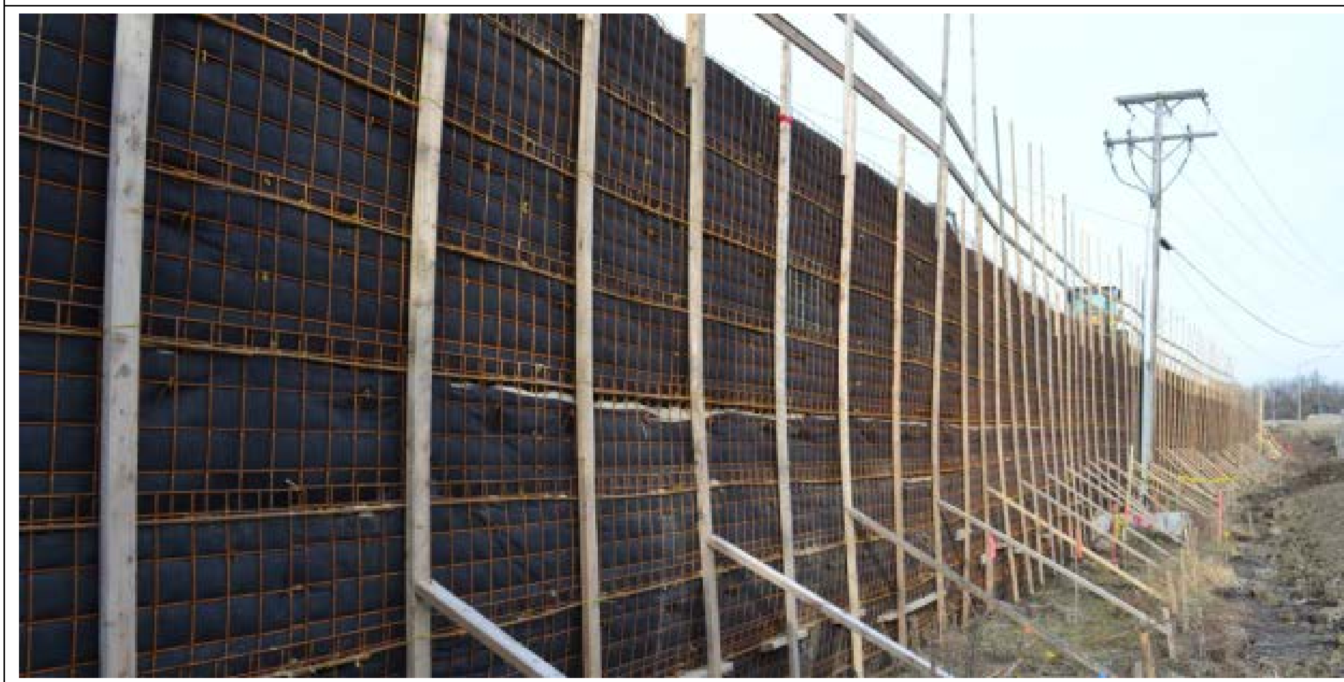
Soldier piles and lagging to transition from the existing sloped embankment.

Soldier piles with the lagging being installed.

Temporary Retaining Wall constructed with soldier piles and lagging.

Temporary Modified Structural Earth (MSE):

Temporary MSE Wall was completed with 18 inch baskets.
Ties were buried in select backfill to provide support.



Temporary MSE Wall completed in 18 inch baskets.

What is Design Build? This is a contract between the owner and the contractor where-by the contractor selects and designs their solution to solve the specific construction issue -- in this case, the Temporary Soil Retention System. Their engineering team designs their solution, provides a structural engineer to stamp and be responsible for the design, and then constructs it. The plans are reviewed and commented on by the owner during the bidding process. If the review is positive, the contractor includes the cost of their method in their bid. Final details are prepared by the contractor upon being awarded the contract, reviewed and accepted by the CM Team and the owner, and used for construction.

Piles

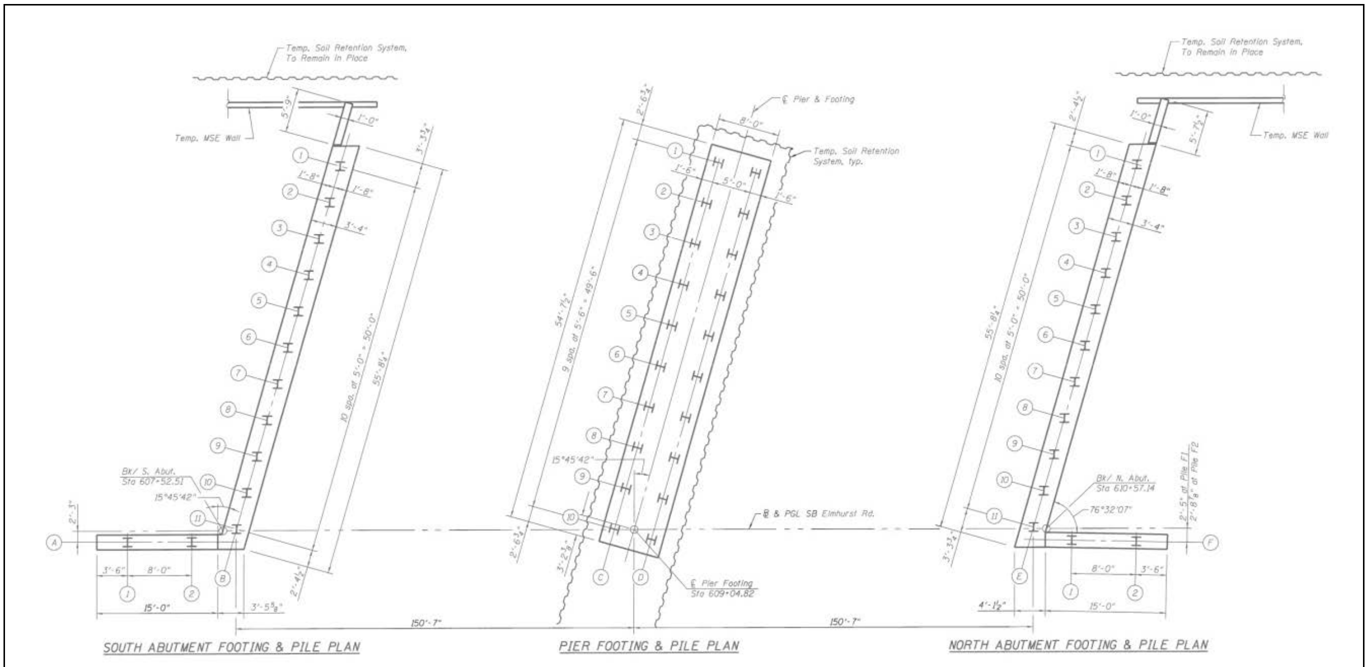
The piers and abutments for Russell's Bridges were all supported by piles to provide a more stable structure than would be created if they were constructed directly on the subgrade and they will minimize sinking and movement of the structures in the future. A Soils Report was prepared by geotechnical engineers for each structure and provided information about the depth to bed rock, depth and types of soils, water tables, and related soil characteristics. The information was used by structural engineers to estimate the length and type of piles.

The design engineers calculated the Nominal Required Bearing Load (NRBL) to include the bridge weight, the traffic load, and environmental factors. They proportionately transferred that load to each pile and included the information on the plans. The NRBL is the force required to drive the pile, measured in 1,000 pounds-force (kip), in order to resist the load that was placed on it.

For Russell's Bridges, structural engineers selected either H-beam steel piles or shell cast in place pipe piles. Most piles were pounded straight into the ground but some had a batter, which is a slight vertical angle.

In order to verify the pile length identified in the plans, one test pile was installed at each abutment and pier. The test pile provided a more accurate pile length than the length shown on the plan because it was based on actual field conditions, not estimated soil characteristics. Even so, the length of pile actually pounded into the ground varied significantly, as can be seen in the pictures. For Russell's Bridges, the installed pile lengths varied from approximately 50 feet to approximately 110 feet into the ground.

Each pile was pounded into the ground by a diesel hammer, held by a crane with a boom and supporting cage. The hammer was a known weight and it dropped a known distance to produce a calculated load on the pile. Certified piston weight and travel distance, for each hammer, were provided by the contractor. The number of blows to reach the NRBL was calculated by both the contractor and the CM Team (See Formula below). The contractor marked each pile in 1 foot increments, so both the QA and QC Inspectors could count the number of blows per foot until the NRBL was reached.



A typical Plan Detail to show the proper location of the piles. Piles were staked by surveyors with these details.

Semi-trailer delivering 85 foot H-piles. A special permit was required for this truck to travel on the highway.

Stockpiled H-piles marked at 1 foot intervals by the contractor's field engineer and ready for installation.

QC and QA Inspectors counting blows per foot during pile driving.
They solved the following calculation to determine that the pile reached the proper depth.

Art. 512.14 Piling

512.14 Determination of Nominal Driven Bearing. The nominal driven bearing of each pile will be determined by the FHWA modified Gates formula as follows.

$$R_{NDB} = 1.75\sqrt{E}\ Log\left(10N_b\right) - 100 \quad \text{(English)}$$

$$R_{NDB} = 7\sqrt{E}\ Log\left(10N_b\right) - 550 \quad \text{(metric)}$$

Where:

R_{NDB} = Nominal driven bearing of the pile in kips (kN)
N_b = Number of hammer blows per inch (25 mm) of pile penetration
E = Energy developed by the hammer per blow in ft lb (J)

For piles driven on a batter, the value of "E" will be multiplied by the hammer energy reduction coefficient, "U" will be determined as follows.

$$U = \frac{0.25(4 - m)}{\left(1 + m^2\right)^{0.5}} \quad \text{for drop hammers}$$

$$U = \frac{0.1(10 - m)}{\left(1 + m^2\right)^{0.5}} \quad \text{for all other hammers}$$

Where:

U = Hammer energy reduction coefficient, less than unity
m = Tangent of the angle of batter (i.e. m = .25 = 3/12 for 3H:12V batter)

This is a typical engineering formula copied directly from the Specifications. It is used to determine how many blows per foot are required so the pile provides the correct bearing resistance. This equation was solved by the CM Team, was checked by the documentation engineer, and then approved by both the RE and the owner.

Diesel hammer firing to raise and drop the hammer to drive the pile.
The yellow structure is a heavy duty cage to enclose the pile and keep it straight.

These piles are all the same length and driven to the correct bearing depth.

Engineers marked the correct final top of pile elevation and the excess was cut off.

H-piles at center pier cut off at the correct final elevation.

Shell cast in place pipe piles, cut off, and being filled with concrete.

H-piles cut off at finish elevation in an abutment.
Pile casings are visible before select backfill was placed around them.

Abutment H-piles after select backfill was placed and cut off at the correct elevation .

Abutments and Piers

After the piles were properly installed, they were cut off at the elevation(s) identified in the plans. Each pile was designed to extend 4 feet into the pier and 2 feet into the abutment. The abutments were designed to move slightly because of traffic loads and environmental factors, so each pile was encased in a galvanized steel, corrugated metal, casing pipe, filled with sand. The casing pipes provided sufficient area so the pile could move, very slightly, within it without transferring the movement to the adjoining retaining wall. The center pier was a rigid structure, with no movement, so the piles were not encased.

Select backfill was used to backfill the area from the furnished embankment, around the piles, and enclosed by the permanent retaining walls. The approach slab and abutment were then constructed on the select backfill.

The abutments and piers were constructed of poured in place concrete with re-bars. The shapes of the re-bars was designed by structural engineers, each of the shapes was specifically identified on the plans, and then they were manufactured in a plant under the supervision of other civil engineers. Each section of the structure was formed; re-bars were installed, and properly tied; and the concrete was poured, one section at a time. The concrete was properly tested by the QC Inspector and verified by the QA Inspector during the pour, it was cured, and then tested at 3 and 7 days to verify that it reached the required strength (See Concrete Testing). 3,500 psi was the typical strength. Once this strength was reached, the next sections could be poured, but not before.

The top of the piers and abutments were stepped so the deck would slope to match the proposed street pavement. Streets are designed and constructed with a transverse slope, (+/-) 2%, to provide positive surface water drainage and improved vehicle traction for the motoring public.

Why are re-bars green? Engineers learned many years ago that re-bars rust when exposed to salt. Since concrete is not perfectly water tight, a small amount of water passes through it. Road salt, in the northern climates, or sea salt, near the ocean, combines with oxygen to rust the bars. The rusted re-bars expand, causing tensile stress in the concrete, and, since it is weak in tension, spalling results. To keep the re-bars from rusting, they are coated with epoxy. The CM Team randomly inspected the bars to verify that the epoxy was not compromised to expose bare re-bars.

What is Select Backfill? Select backfill is a loose, self-compacting, dry material, with a gradation that includes only a very minimal amount of fines. Common materials are "Pea Gravel" and "Sand". Because it is dry and loose, and includes minimal amount of fines, it requires minimum compaction to reach maximum density, and provides a very stable fill material for the abutment and approach slab, and an effective retaining material for MSE Wall tiebacks.

What is Cubic Yard? Cubic Yard is a unit of volume measure common in civil engineering. It is a three dimensional measurement, 3 feet by 3 feet by 3 feet, which means 1.0 cubic yard is equal to 27.0 cubic feet.

All the re-bars were designed by civil engineers and then manufactured, inspected, and certified in a plant. The installed system was inspected, measured, and documented by the CM Team.

Epoxy coated re-bars and forms for the center pier.

Epoxy coated re-bars were extended into the diaphragm and are ready
for the forms and concrete.

Contractor making a final measurement to verify proper form position.

Filling a 2 yard concrete bucket.
The concrete from this truck was tested by both the QA and QC Inspectors.

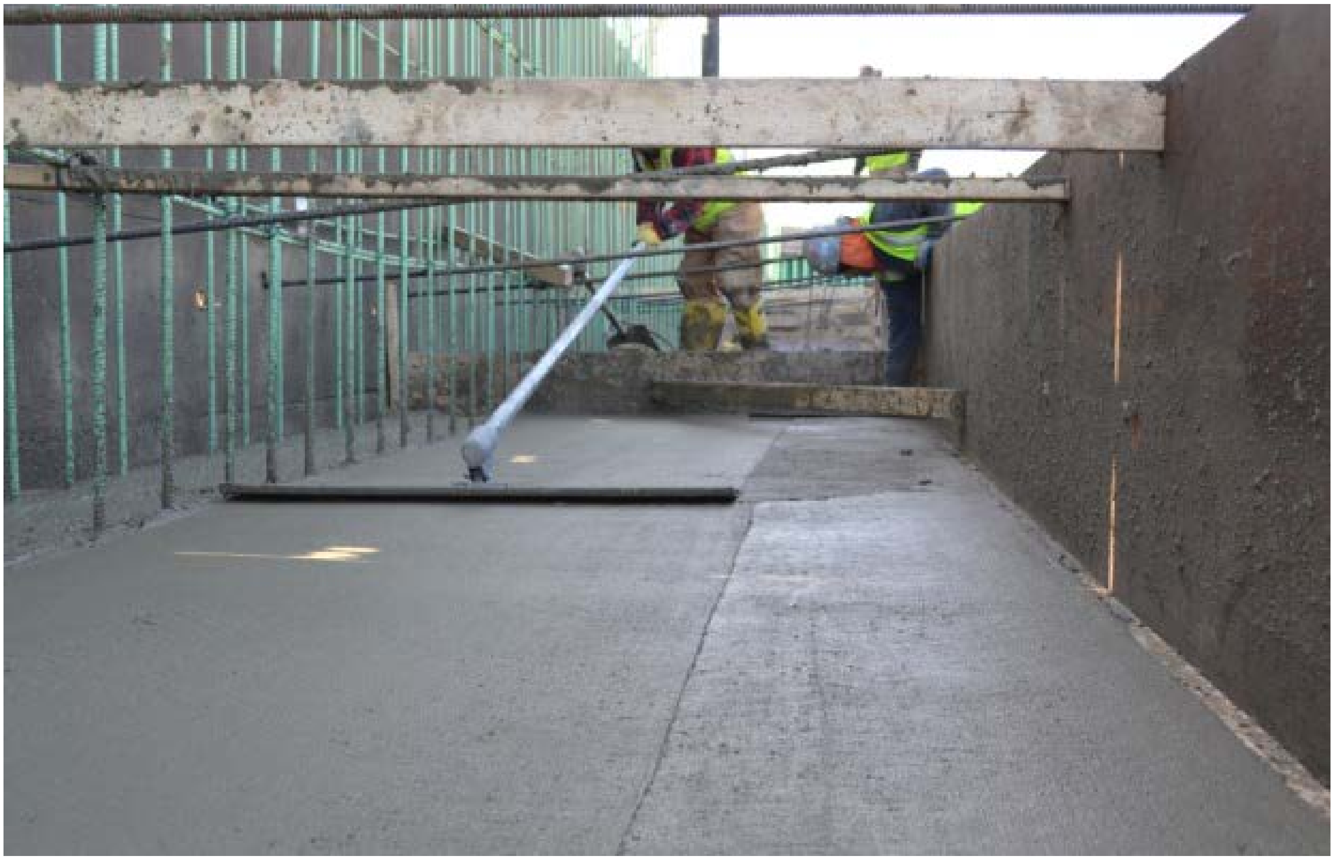
Pouring concrete with a bucket.
When concrete must fall more than 6 feet, it must be installed with a chute.
The CM Team verifies proper concrete placement.

Concrete truck supplying 9 cubic yards and being pumped with a concrete pump.

Concrete flowing from a concrete pump.

Concrete being placed into the abutment.

Finishing concrete for the abutment.



Finishing concrete for the abutment.

Detail of stepped abutment.

<u>Testing Concrete</u>

Another very important item tested by the CM Team was the poured-in-place concrete. Several different concrete mixes, with different compositions of cement, aggregate, water, and chemical additives were specified in the contract documents. Civil engineers, specializing in materials, working for the contractor, submitted mix designs to show how the materials would be combined and blended to provide the concrete mix that met the contract documents. The CM Team material coordinator reviewed the mix designs, worked with the contractor to correct any deficiencies, and recommended approval to the owner.

Four different concrete tests were performed in the field -- for air content, slump, strength, and temperature. They were completed by both the QC and QA Inspectors as directed in the contract documents. In some specific, sensitive cases, such as the bridge deck, civil engineers for the material supplier also performed the tests. They were completed from a random selection of trucks, based on the quantity of concrete being poured, usually 50 cu. yd. maximum, as required in the contract documents. Each test required different pieces of equipment and an experienced civil engineer to perform them.

1. <u>Air Content:</u> Civil engineers have determined that concrete exhibits different characteristics with differing amounts of air entrained in it. Air entraining agents were used to effect the finished concrete and were used with each cubic yard of concrete to provide the proper characteristics. The percentage of air was specified at between 5.0 and 8.5% for the piers and abutments.
2. <u>Slump:</u> This is a length measurement and refers to how far a cone of fresh concrete will settle after the cone was removed. It was a direct function of how much water was in the concrete, although it can also be influenced by certain chemicals that increase slump without adding water. Low slump concrete had a very low water ratio and exhibited a slump of about 1/2 inch. Chemicals were added to allow it to be finished before it became too “stiff” to work and handle. Very liquid concrete, with a slump of 5 or 6 inches was required for pumping and chemicals were not needed. The maximum slump was specified at 4 to 6 inches for the piers and abutments.
3. <u>Compressive Strength:</u> The concrete must reach a specified compressive strength before it was ready for the next steps. To test the concrete, the QC Inspector created concrete cylinders, let them cure for either 3, 7, or 14 days, and then tested them by crushing them in a laboratory. The compressive strength was specified at 3,500 psi for the piers and abutments.
4. <u>Temperature:</u> Even in the most extreme weather, the liquid concrete must cure – not freeze. In cold weather, hot water was added, and in hot weather, cold water was added to allow the concrete to properly cure. In cold weather, the fresh concrete was covered with thermal blankets and heat was blown into the blanketed concrete. The temperature of the fresh concrete was checked from the truck to verify that it was in an acceptable range.

Testing Concrete for Air Content:

Loading the canister for air.
Fill at one-thirds and 25 plunges of the rod are required for proper consolidation.

Canister loaded, smoothed, cleaned, and ready to cover with the meter.

Filled and pressurized canister showing the percentage of air.
Between 5 and 8% is required.

Testing Concrete for Slump:

Loading the cone for slump.
Fill at one-thirds and 25 plunges of the rod are required for proper consolidation.

Cone being removed.
Slump begins as soon as it is removed.

The slump is measured. The pump truck can pump concrete with 4” of slump.

Testing Concrete for Strength:

Cylinders properly marked for identification.

Filling the cylinders.
Fill at one-thirds and 25 plunges to properly consolidate.

Cylinders were stored in an ice chest against the cold to cure for 3, 7, or 14 days.
They were taken to a laboratory where they were broken by a civil engineer to determine their strength.

Testing Temperature of Concrete from Truck:

Temperature is also checked.
Thermometer says 60 degrees.

PERMANENT RETAINING WALLS

Two types of permanent retaining walls were specified on the Plans and were constructed – one was a Mechanically Stabilized Earth Retaining Wall (MSE Wall) and the other was a Structural Concrete Wall on Footing (SCW). The final details of the permanent retaining walls were prepared by the design engineer and included in the contract documents, so the contractor did not have the option of selecting other methods.

Modified Structural Earth:

MSE Walls were precast concrete panels, about 6 inches thick, designed by structural engineers; manufactured, inspected, and certified in a plant; and transported to the site. Each panel was tested, inspected, and certified by civil engineers at the plant. Each wall was composed of many panels with particular shapes to match the wall profile and surface texture designed by the owner and shown on the plans. The panels were installed on a concrete footing, in sequence from bottom to top. Tieback straps were connected to the panels, installed perpendicular to the wall, and buried within the select backfill which was placed and compacted over the straps to stabilize and hold the panels in place. Perforated PVC pipe was installed to provide drainage and prevent water pressure from building up behind the wall. Structural engineers, working for the contractors, certified that this combination of tiebacks, drain pipe, and select backfill would support the required wall. Each contractor provided final design details of the panels, including connection details, reinforcing mesh, and dimensions, to the CM Team, who then reviewed them, worked with the owner for approval, inspected their installation, and measured them for payment.

MSE Wall panels ready for installation.
They were designed, certified, and manufactured at a plant under the direct supervision of a structural engineer.
Note that each panel has identification because it goes in a certain location.

Footing for MSE Wall.
A surveyor staked the horizontal and vertical position for the contractor to construct.

The rear of the MSE Wall during installation.

Tieback straps properly spaced to support the wall and ready to be covered with select backfill.

Tieback strap connection detail.
This select backfill is called “Pea Gravel”.

Select backfill being placed, graded, and properly compacted.

Drainage pipe to relieve pressure from water build-up.

Front of MSE Wall with coping. Construction is nearly complete.

Structural Concrete Wall with Footing:

The SCW was connected by stud shear connectors to the piles used for the soldier piles and lagging. A concrete footing was poured below frost level, forms were built around the re-bars, and the concrete was poured about 8 inches thick. The CM Team inspected construction of the SCW and measured it for payment.

Soldier piles with stud shear connectors ready for re-bars, forms, and concrete.

Stud shear connectors welded to soldier pile.
The CM Team tested for proper connection by bending 45 degrees.
“Just hit it real hard with a heavy hammer!”

The contractor and CM Team reviewing the plans to insure proper re-bar layout.

Re-bars in place ready for forms.
The CM Team verified and measured the re-bars for payment.

Completed Structural Concrete Wall with Footing.

Beams

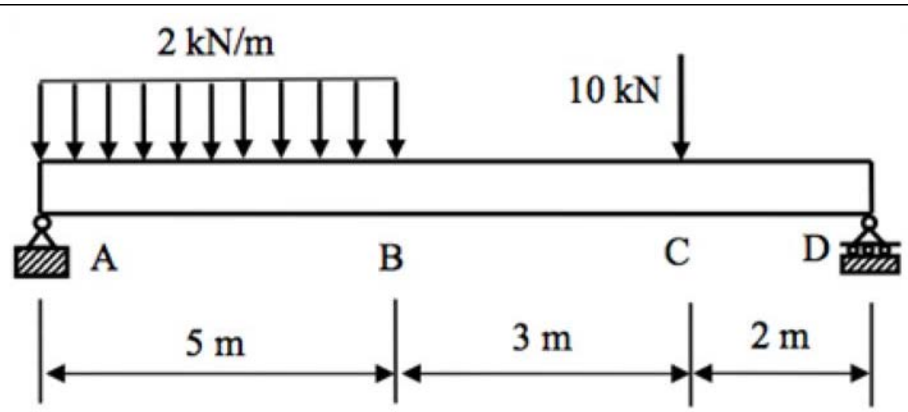
The beams for Russell's Bridges had to span the pavement from an abutment to a center pier. The span length varied from 107 feet to 280 feet. This means that some beams had to straddle half a football field – from the 50 yard line to the goal post. The design civil engineers used the classic beam diagram (see picture) to design both the concrete and steel beams based on the length and load they had to support. The shorter beams, which could be concrete, were about 6 feet deep, while the longer beams had to be steel, were spliced together to provide the total length, and were about 10 feet deep.

Both steel and concrete beams were so long that special permits were required to haul them to the sites on semi-trailer trucks. They were removed from the trucks and raised into place with cranes. Concrete beams were only used when they could extend from abutment to pier. Steel Beams were used when they had to be spliced together to span that length. Each splice included splice plates and bolts on the top flange, bottom flange, and web. Both the concrete and steel beams were stabilized and strengthened by cross members bolted to them.

The position of the beams was continually checked during installation by surveyors for the contractor and then their final position was verified by surveyors for the CM Team.

The design engineers included basic design parameters in the plans, such as span length, load, and profile, but structural engineers employed by the contractor and manufacturer were responsible to design the details, stamp the entire process, and manufacture, inspect, and certify them to meet the contract documents. Details included such things as the plate size and thickness, the type, size, and number of bolts, the number and size of welds, and the re-bars. This information was submitted to the CM Team as Shop Drawings, it was reviewed and approved by the CM Team and the owner, inspected during construction by the CM Team, and measured for payment.

Since Russell's Bridges were constructed over live traffic, the beams were installed between the hours of Midnight and 5:00 am. Special lane closures allowed the police to close the entire roadway in no more than 15 minute increments. In that 15 minute time period, the contractor had to lift and set a beam, butt it together, install a minimum of 50% of the bolts, and place the combined beam in the correct position on the abutment, pier, or temporary support. Time was critical, and these hours were specifically chosen, because, even between midnight and 5:00 am, the traffic count was several thousand cars, so short traffic stops were required to minimize traffic congestion.



The classic diagram for a simply supported beam, fixed at one end and movable at the other.
Commonly used to design all bridges.
Civil engineers solve the equations associated with this diagram to determine the required beam size and shape.

Steel Beam:

Steel beam, 10 feet (H) by 110 feet (L).

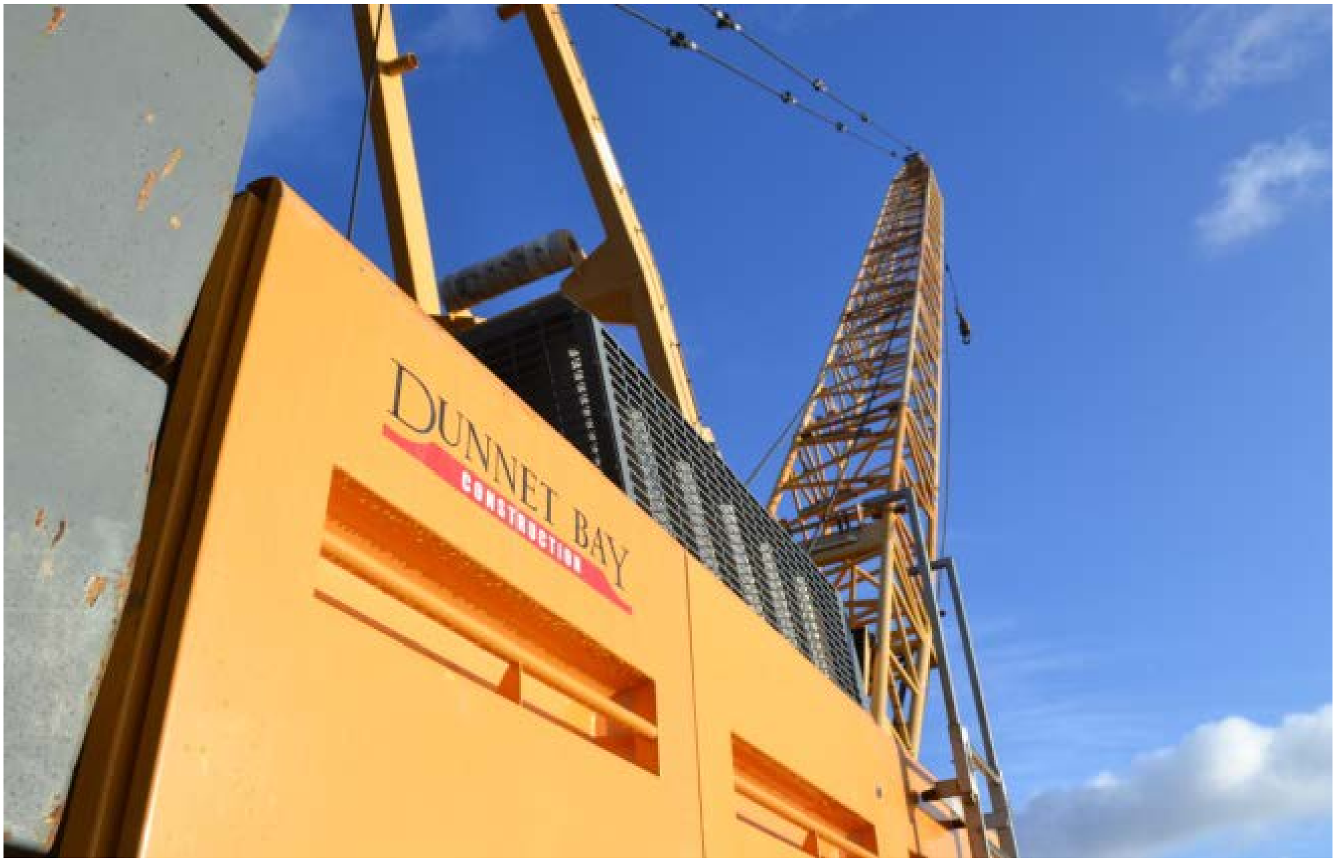
Raising steel beam. Crane is 300 ton capacity with 160' boom.
Note that the pavement is closed.

Raising a beam and getting close to the splice.

Beam being connected at a splice.
The CM Team verified that a bolt was placed in each hole and was correctly tightened.

Splice plate and bolts on top flange, bottom flange, and web.

End of beams awaiting extension and proper connection.



The contractor used a 300 ton crane with a 160 foot boom.
All of this equipment was designed by engineers.

Cross members bolted to the beams.

Center pier with fixed bearings. The beams will sit on these bearings.
Surveyors have already verified the horizontal and vertical location of these bearings.

Multi-rotational disc bearing on an abutment for the movable end.
It was designed to allow the beam to slide and rotate.

Concrete Beam:

Concrete beam waiting to be off-loaded from the delivery truck.
The beam has already been tested, inspected, and certified at the manufacturing plant.

The stamp showing that the beam was inspected during manufacture and met the requirements.

A concrete beam, 6 feet (H) and 100 feet (L).

The beam being lifted to straddle from abutment to pier.

The contractor used a 600 ton crane with a 164 foot boom.
All of this equipment was designed by engineers.

A fixed bearing for the concrete beam. This end will be buried into the concrete diaphragm.

Testing Bolts

A fourth very important test was to verify proper bolt installation. A typical bridge contained more than 3,500 bolts and the CM Team tested and properly documented a random sample of them to verify that they were properly torqued (i.e. tight enough). Two different tests were performed:

1. The CM tightened three random bolts to a minimum of 50,000 ft-pounds force to prove that they would not strip or break.
2. The CM then randomly tested 10% of the bolts to verify that the bolts were properly tightened to a minimum of 40,000 ft-pounds force.

The torque wrench was properly calibrated at a laboratory, by a civil engineer. The contractor provided the test results to the CM Team. Note that the wrench required an extra long handle so enough torque could be applied. The CM Team and contractor jointly performed Test 1 and the CM Team performed the random tests.

The CM Inspector and contractor testing bolts to verify a torque of 50,000 ft-pounds force before breaking or stripping.

The CM Inspector testing a random flange bolt to verify that the proper torque was applied.

Bridge Deck

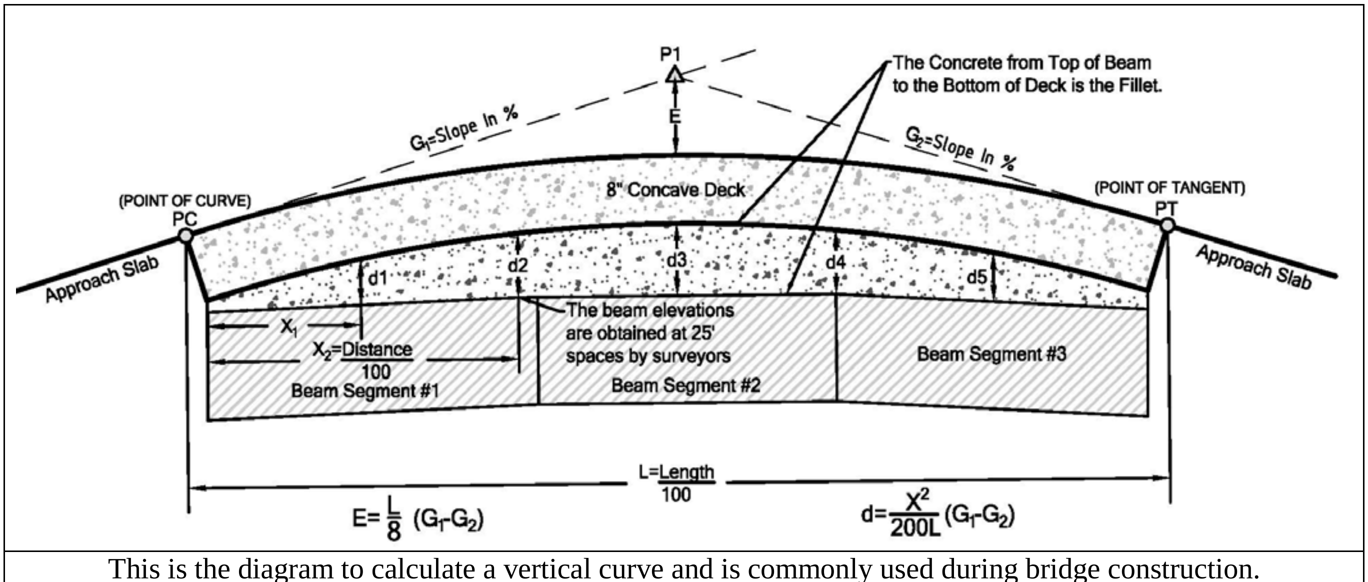
The bridge deck was the final component of Russell's Bridges. It consisted of a reinforced concrete deck, 8 inches thick, with outside parapet walls, drainage structures, and lighting. The deck surface was concrete, with a broomed surface, rough enough to provide traction but smooth enough to carry vehicles and pedestrians. It had a transverse slope (+/- 2%) to provide positive drainage and it followed the street profile.

To safely construct the final, finished concrete deck, the contractor constructed three different layers:

- **Protective Shield:** The bottom layer temporarily straddled the gap between the beams. It consisted of wood 6x4's placed on the bottom flanges and covered with plywood. Since the protective shield was the bottom layer, above pavement with live traffic, lanes had to be closed, and traffic shifted or stopped during installation to prevent tools, materials, and/or equipment from falling on the traffic. To increase workers safety, they were "tied off" to the beam while they installed the shield to prevent them from falling. Don't forget, it was about 18 feet from the bottom flange to the pavement below. Part of this layer was measured and paid for after inspection by the CM Team.
- **False Deck:** The middle layer was also a temporary structure, it filled the gap between the upper flanges, and was the surface upon which the concrete bridge deck was poured. Like the protective shield it was built with wood structural members covered with plywood. Since the protective shield was already installed, the contractor and CM Team could access the false deck by walking on the protective shield. This work was inspected by the CM Team but was not a separate pay item.
- **Concrete Deck:** Re-bars were properly placed and the permanent, finished, 8 inch concrete deck, was poured on the false deck. Both the false deck and the protective shield were removed after the concrete was properly cured. The CM Team inspected and measured the finished decks.

The top flange was smooth enough that the concrete used for the deck would not adhere to it. Therefore beam connectors were installed, either by welding studs to the steel beams or integrating re-bars and manufacturing them with the concrete beams.

The fillet was concrete, poured with the deck, of variable thickness, so the finished deck elevation met the proposed pavement profile while providing an 8 inch minimum concrete deck. They made the final adjustment between the beam and the finished concrete surface. A fillet height between 0 and 4 inches was calculated by the contractor's surveyor and verified by the CM Team.



This is the diagram to calculate a vertical curve and is commonly used during bridge construction.
Civil engineers solve the equations to calculate the fillet height, "d".

Protective Shield and False Deck with Fillet:

The protective shield was constructed first
by setting it on the bottom flanges.

The protective shield was used to construct the false deck.

The false deck under construction.
The fillets assured that the final position of the 8 inch deck was at the proper elevation.

When a beam was more than 6 feet deep, OSHA requires the worker or inspector
to be “tied off” to prevent falling. This is the correct equipment and method.

Fillet height = 2 3/4" on a concrete beam so the deck will be at the proper elevation.
The height was calculated by the contractor's engineer and verified by the CM Team.

Fillet height = 4 5/8" on the steel beam so the deck will be at the proper elevation.
The height was calculated by the contractor's engineer and verified by the CM Team.

Beam Connectors:

Shear stud connectors are welded to the top flange of the steel beams as beam connectors.

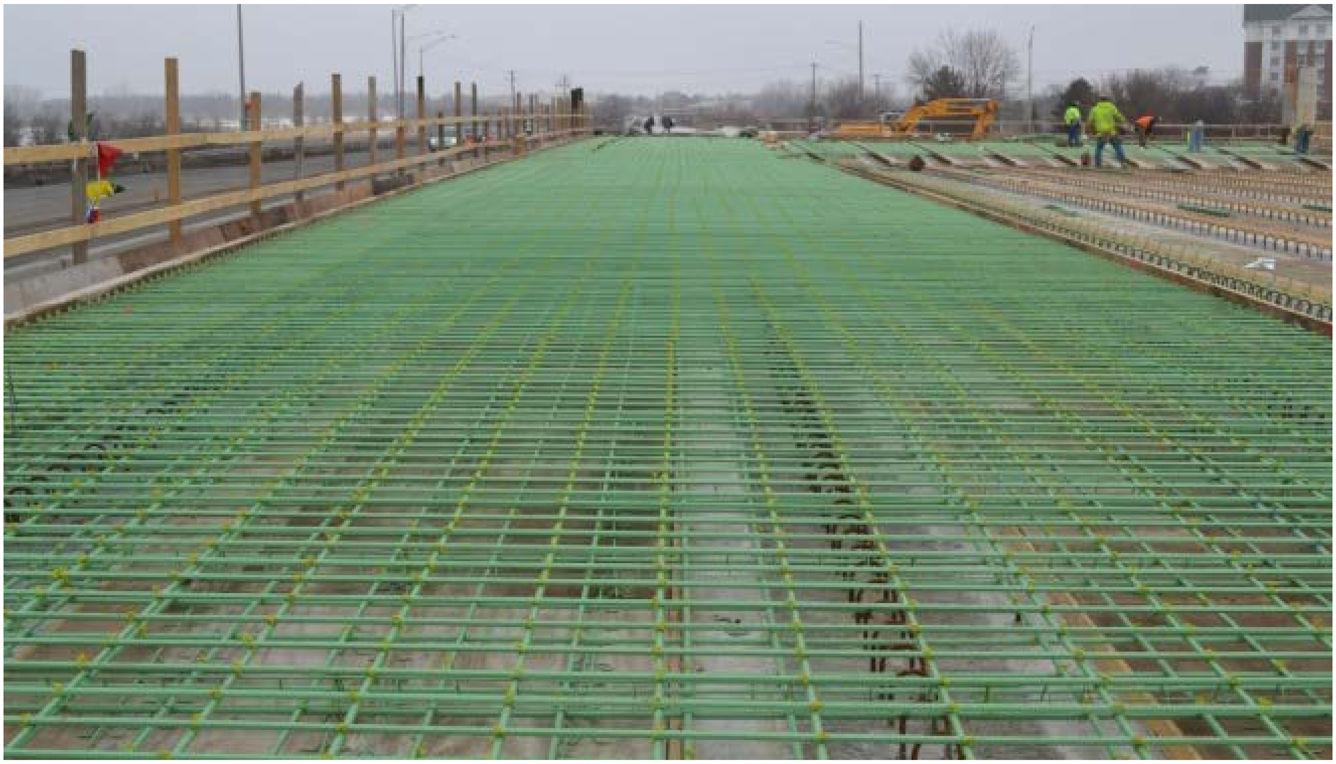
The CM Team tested a random sample by bending them to 45 degrees to verify that they met Specifications.

Concrete beam connectors were manufactured with the concrete beam.
Civil engineers at the plant certified that the connectors met the contract documents.

The deck rebars were integrated with the beam connectors
to provide suitable attachment of the deck to the beams.

Concrete Deck:

All re-bars were designed and shown on the plans.
The CM Team used the plans to verify the proper size, shape, overlap, and placement of the bars.

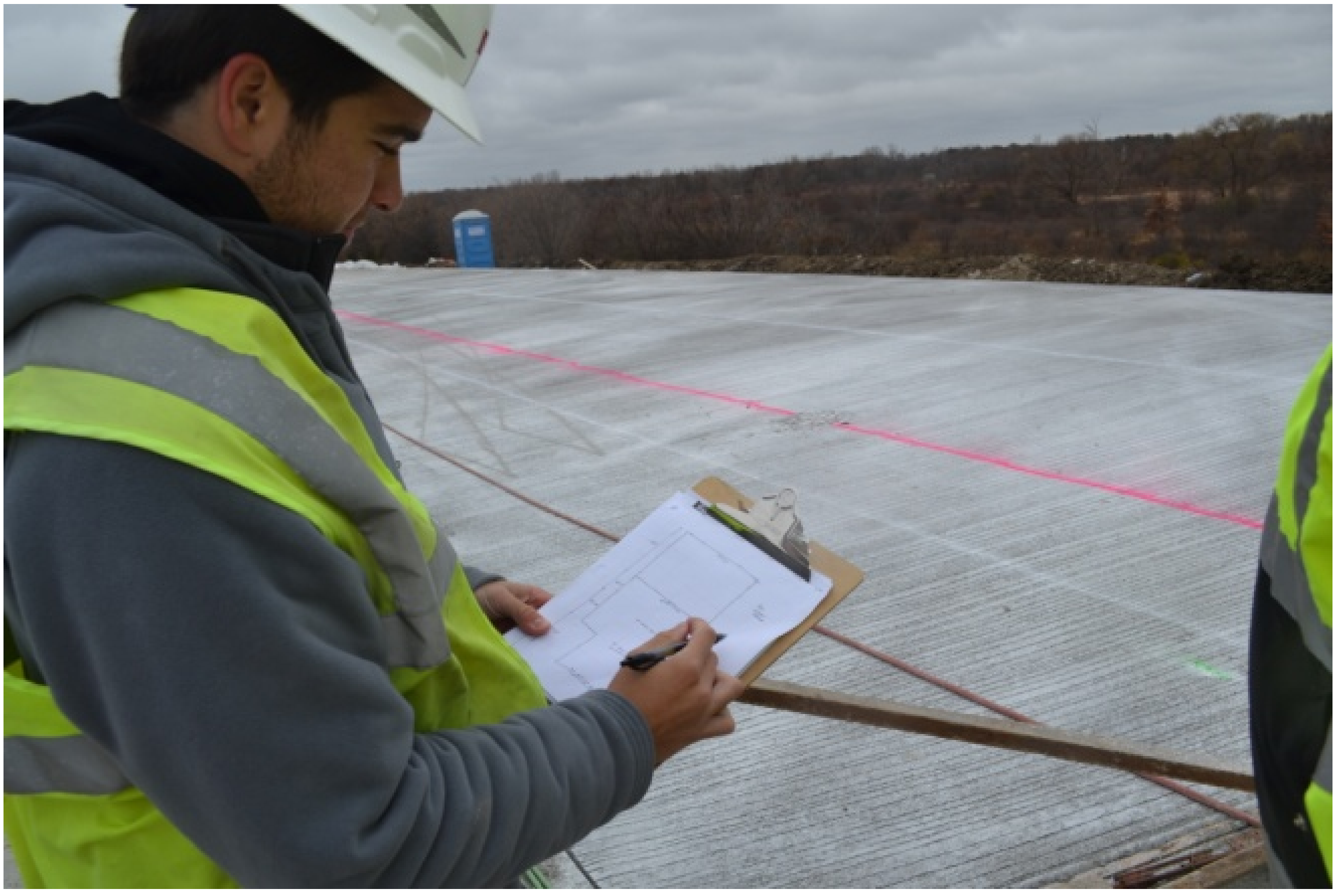


Re-bars in the proposed deck properly placed, tied, and ready for concrete.

The QA Inspector periodically checked the concrete deck thickness during the pour.
If questions arise, cores are sometimes taken to verify the proper deck thickness.

A broomed finish was applied to obtain proper vehicle traction.

The fresh concrete was covered to properly cure for a minimum of 7 days.



The CM Team measured the finished deck area for payment.

The CM Team measured the finished deck area for payment.

Parapet Walls:

The barricade wall was constructed integral with the deck.

Re-bar and electrical conduits were installed before concrete was poured.

Conduit for lighting and message boards was designed and inserted into the barrier wall.

The finished parapet wall with a pedestrian railing.

A typical, two-span bridge with abutments, a center pier,
permanent retaining walls at the ends and along the sides,
concrete beams to span the pavement,
and a concrete deck with wearing surface for the vehicles to ride on.