Accelerated Bridge Construction in USA

Abstract

Rush hour traffic is a common daily occurrence in the USA. Highway and bridge construction further aggravates the situation. The Federal Highway Administration (FHWA) and the Departments of Transportation in several states are looking for ways to expedite construction. The Accelerated Bridge Construction (ABC) initiative is the result of this. It is accomplished in two ways; accelerated construction of bridges in place or moving completed bridges to position by using moving technology.

Reduced disruption to traffic due to faster construction, enhanced safety due to reduced exposure of workers to construction activities, better quality control as most of the components are fabricated offsite, reduced environmental issues due to fewer construction activities on site, and lower costs are some of the advantages of Accelerate Bridge Construction. This is achieved by the use of Prefabricated Bridge Elements and Systems (PBES) in the bridge superstructures and substructures or building entire spans off site and moving them to the final location.

In this paper, various prefabricated elements used in bridge superstructures, substructures, and retaining walls are presented.

Key Words: Accelerated Bridge Construction, Prefabricated Bridge Elements, Segmental Piers

1. Introduction

Rush hour traffic is a common daily occurrence in the USA. Highway and bridge construction further aggravates the situation. The Federal Highway Administration (FHWA) and the Departments of Transportation in several states are looking for ways to expedite construction. The Accelerated Bridge Construction (ABC) initiative is the result of this. It is accomplished in two ways; accelerated construction of bridges in place or moving completed bridges to position by using moving technology.

Reduced disruption to traffic due to faster construction, enhanced safety due to reduced exposure of workers to construction activities, better quality control as most of the components are fabricated offsite, reduced environmental issues due to fewer construction activities on site, and lower costs are some of the advantages of Accelerate Bridge Construction. This is achieved by the use of Prefabricated Bridge Elements and Systems (PBES) in the bridge superstructures and substructures or building entire spans off site and moving them to the final location.

Higher initial costs, durability of joints, perception of ABC as raising the risk of projects, concerns about the performance of ABC connections under seismic loading are some of the challenges for ABC. Further, contractor related issues such as local contractor preference for cast-in-place concrete, the fact that ABC gives work away to pre-casters, requirement of specialized equipment for erection also add to the challenges.

Various prefabricated elements used in bridge superstructures, substructures, and retaining walls are presented below.

2. Prefabricated Bridge Elements and Systems (PBES)

2.1 Deck Systems

Prefabricated precast concrete deck panel systems are widely used. They can be precast post-tensioned deck panels or proprietary systems.

2.1.1 Precast Post-tensioned Decks

This is the most common prefabricated precast concrete deck panel system. Figure 1 shows this system. The panels are placed on the stringers and post tensioned in both longitudinal and transverse direction. The shear connector pockets are filled with grout. The use of post-tensioning will reduce deck cracking and the deck thickness. Reduction in deck thickness results in the reduction of concrete and steel, and wider girder spacing in new construction is possible. Wider girder spacing will reduce the fabrication time as the number of girders and cross-frames to be fabricated and painted will be reduced. It will reduce the erection time since there will be fewer pieces to be erected and a fewer bolts to be tightened. It will require fewer bearings to be purchased, set and maintained.

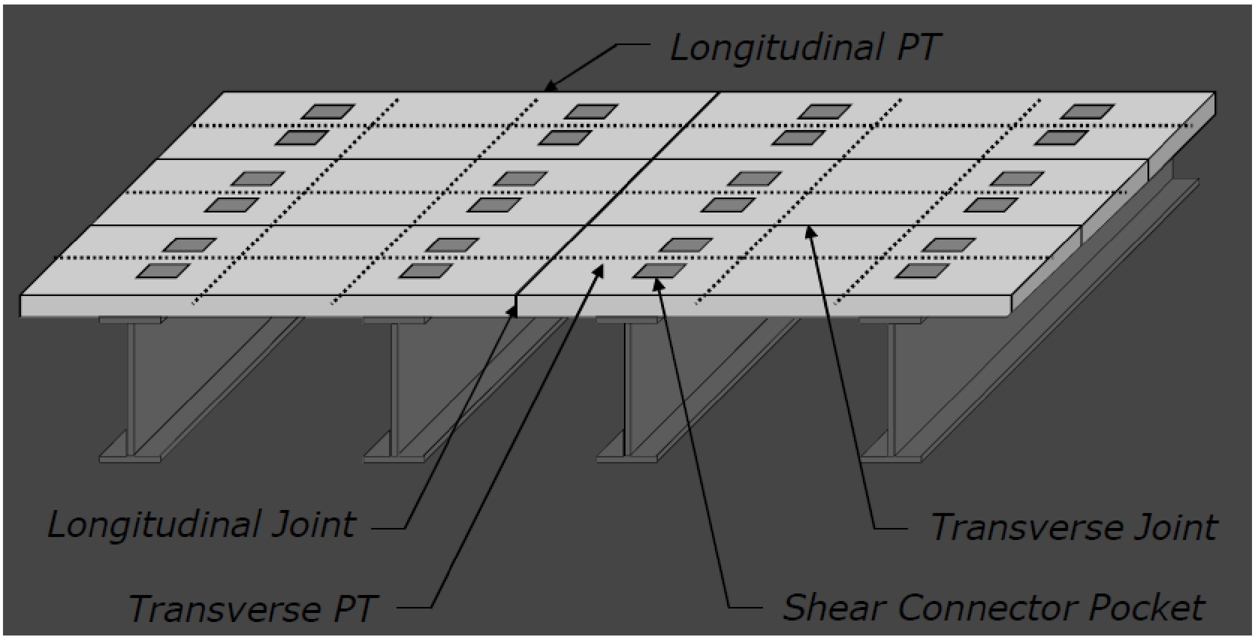

Figure 1: Precast Post-tensioned Deck Schematic

2.1.2 Precast Pre-tensioned Stay-In-Place Deck Forms

Precast pre-tensioned concrete Stay-In-Place (SIP) deck forms are used in place of steel SIPs. The precast SIP forms become a part of the permanent deck thickness. Compared to the steel SIPs, the precast concrete SIPs are durable and do not corrode and they do not add extra weight on the girders since they become part of the deck.

2.1.3 Exodermic Decks

An Exodermic (defined as “composite, unfilled steel grid”) deck is comprised of a reinforced concrete slab on top of, and composite with, an unfilled steel grid. This maximizes the use of the compressive strength of concrete and the tensile strength of steel. Horizontal shear transfer is developed through the partial embedment in the concrete of the top portion of the main bars that are punched with 3/4" holes. Overall thickness of the system using standard components ranges from 6" to 9 ½"; total deck weights range from 39 to 74 pounds per square foot. Exodermic decks using standard components can span over 18 feet. Larger main bearing bars and/or thicker concrete slabs can be chosen to span considerably further.

The concrete component of an Exodermic deck can be cast-in-place or precast before the panels are placed on the bridge. Where the concrete is cast-in-place, the steel grid component acts as a form, the strength of which permits elimination of the bottom half of a standard reinforced concrete slab. Exodermic decks are made composite with the steel superstructure by welding headed studs to stringers, floor beams, and main girders as appropriate, and embedding these headed studs in full depth concrete.

This area is poured at the same time as the reinforced concrete deck when the deck is cast-in-place, or separately when the deck is precast. See Figure 2 for a schematic of a typical Exodermic deck section.

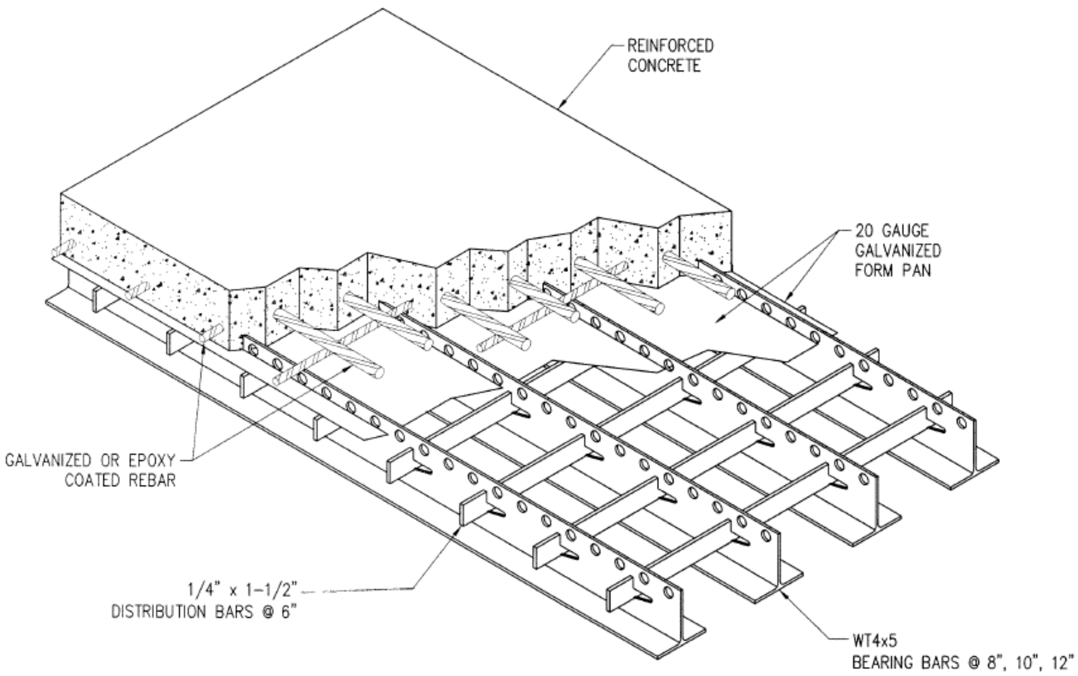

Figure 2: Exodermic Schematic

Exodermic decks work very much like standard reinforced concrete decks. In positive bending, essentially all of the concrete is in compression and contributes fully to the section. The main bearing bars of the grid handle the tensile forces at the bottom of deck. Because the steel and concrete in an Exodermic deck are used more efficiently than in a reinforced concrete slab (wherein the concrete at the bottom of the deck is considered 'cracked' and provides no practical benefit), an Exodermic design can be substantially lighter without sacrificing stiffness or strength. The neutral axis is located near the welds and punch-outs of the grid. This keeps the live load stress range low at these locations, generally eliminating fatigue as a limiting factor in design.

Similarly, in negative bending, the rebar in the top portion of the deck handles the tensile forces, while the compressive force is borne by the grid main bearing bars and the full depth concrete placed over all stringers and floor-beams. Rebar can be selected to provide significant negative moment capacity for longer continuous spans and sizable overhangs. Again, the welds and punch-outs in the grid are located close to the neutral axis, so fatigue rarely limits design.

2.1.3 Effideck Deck System

It is a lightweight deck system consisting of a thin concrete deck slab supported by closely spaced structural steel members cast compositely. The structural steel members span transversely across steel stringers or longitudinally between floor beams of a truss or a through-girder bridge. The deck thickness is approximately 5" making its weight 75 pounds per square foot. The concrete is high-strength, high performance type. The tubes and studs are hot-dipped galvanized, inside and out. Internal composite action between tubes and the deck is accomplished using headed studs welded directly to structural steel tubes. External composite action between the Effideck panels and supporting stringers is accomplished using nested, headed (and sometimes threaded) stud shear connectors welded directly to the stringers through the grout pockets. Steel members are typically pre-stressed during fabrication, providing a pre-compressed concrete deck that resists live load cracking. Un-grouted panels serve as work platforms to erect more panels. Unique attachment details allow for rapid, economical, top-down installation. Panels may be used immediately upon erection because they are supported by steel shims positioned directly on the stringers or floor beams and bolted securely in place. Grout placed in pockets around steel studs complete the composite attachment to the steel stringers. Panel-to-panel connection using channels that attach tubes of adjacent panels together is standard. Post-tensioning of longitudinal joints (highly recommended if using a rigid overlay) and rebar splicing or mechanical coupling at transverse joints is possible. In order to improve the ridability between joints, the surface can be milled or an overlay, such as LMC or a bituminous layer, can be placed. See Figure 3 for a schematic of a typical Effideck panel.

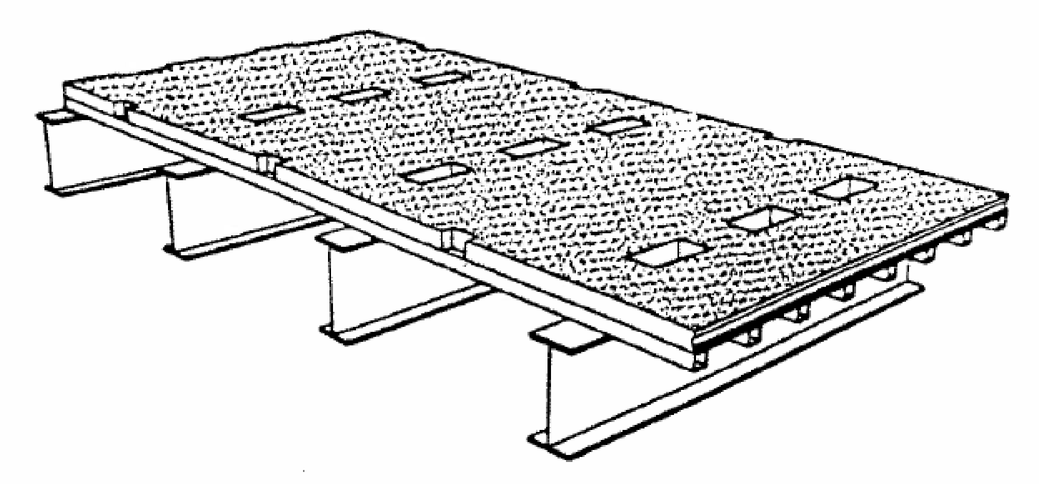

Figure 3: Effideck Schematic

2.2 Prefabricated Superstructure Systems

A few prefabricated superstructure elements are described in this section.

2.2.1 INVERSET System

INVERSET is a precast concrete/steel, composite superstructure system made up of steel beams (typically two or more) and a concrete slab, which act as a composite unit to resist the loads. A cross section of a typical INVERSET unit is shown in Figure 4. The two beams are framed together with shop-installed diaphragms as shown with predrilled diaphragm connection plates for diaphragms that are later installed in the field. The concrete deck is made composite with the steel girders by stud shear connectors. The edges of the deck are keyed. When placed adjacent to each other in the field, the edges of the slabs form a double-grooved keyway which is filled with non-shrink grout and elastic sealing material. Both simple and continuous spans up to 100’ are possible with this system.

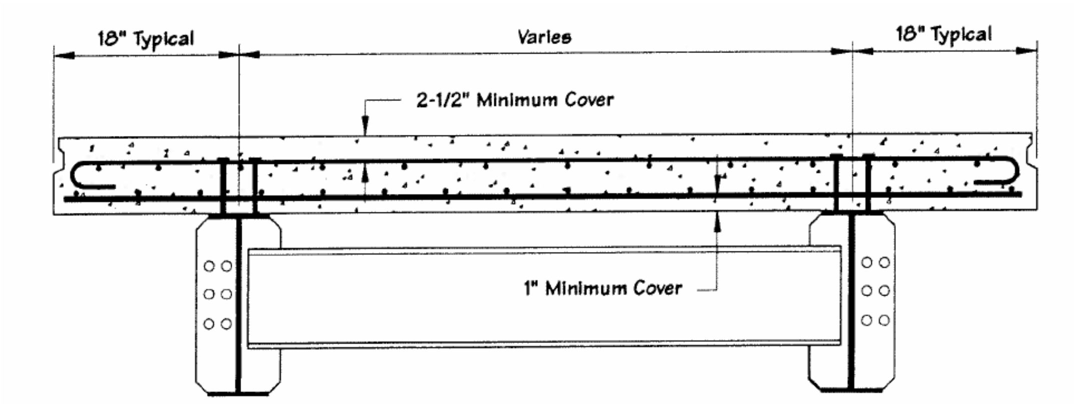

Figure 4: Cross Section of a Typical INVERSET UNIT

2.2.2. NEXT BEAM System

The NEXT BEAM is a pre-stressed concrete bridge double–tee with a 13” wide tee leg that is much stouter than those used in parking structures, for greater strength and shallower depths. It is available in two configurations-an “F” (Form) NEXT BEAM with a partial depth flange serving as the form work for a cast-in-place concrete deck, and “D” (Deck) NEXT BEAM with a full depth flange ready for traffic after installation of a membrane-wearing surface system. This superstructure system is suitable for spans from 30’ to 90’. An “F” Type NEXT BEAM unit is shown in Figure 5.

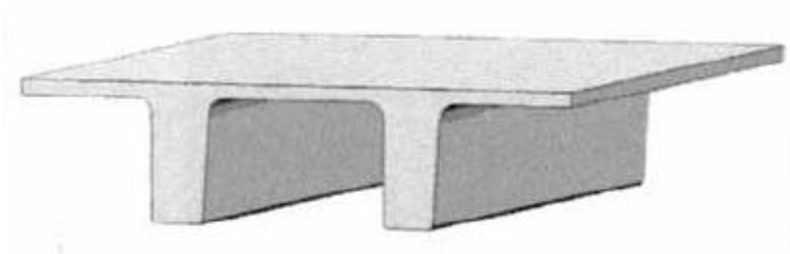

Figure 5: “F” Type NEXT BEAM UNIT

2.2.3. HY-SPAN 3-Sided Bridge System

The HY-SPAN Bridge System is designed as a precast rigid frame. Its flat top may be used as a finished deck or may be designed to accommodate heavy fills over the top of the slab. It is fabricated with skews up to 45^{o} and facilitates staged construction and saves real estate. Typically used where the natural stream bed needs to be preserved, it can also be used on a precast or cast-in-place invert slab. Used with precast footings and wingwalls, an entire bridge can be replaced in a matter of a day or two. This type of bridge can span up to 50’.

2.2.4. CONSPAN Precast Arch System

CONSPAN is a modular precast system for total set-in-place construction of bridges, culverts, underground structures and environmentally acceptable alternatives for underground containment. The arch shape provides an economy of materials for a lower initial cost. The overall savings for a project is significant over cast-in-place construction. Road closings and detours are minimized, resulting in significant reductions in maintenance of traffic costs. This system eliminates two major bridge problems namely, costly maintenance of an exposed bridge deck and bridge deck icing.

2.3 Prefabricated Substructure Systems

There have been significant advances in connection design and their construction in recent years. The new developments try to emulate cast-in-place connections with precast elements. Grouted splice couplers emulate a reinforced concrete construction joint. The coupler replaces the typical lap splice. Grouted post tensioning ducts and grouted cap pockets are other such developments. They have made the precast construction of piers and abutments possible. The prefabricated substructure elements are described in this section.

2.3.1 Precast Piers

In this type of pier, the columns and cap beams are precast and connected in the field through grouted splice sleeves or by using grouted post-tensioning ducts for dowels in caps and foundations. Grouted splice sleeve is an efficient coupler for grouting reinforcing bars which uses a cylindrical-shaped steel sleeve filled with a Portland-cement based non-shrink high-early-strength grout. Reinforcing bars to be spliced are inserted into the sleeve to meet approximately at the center of the sleeve. The interior of the sleeve is filled with the above grout. The resulting splices develop tensile and compressive strengths in excess of the specified strengths of the reinforcing bars. At the precast plant, the sleeves are embedded in the precast element on one end of the main reinforcing bars to be connected. The bars protrude from the other end of the precast member. At the jobsite, the precast members are joined by inserting the protruding bars from the end of one precast member into the sleeves of the adjacent member. The sleeves are then grouted, in effect making the reinforcing bars continuous through the connection. Figure 6 shows a precast pier.

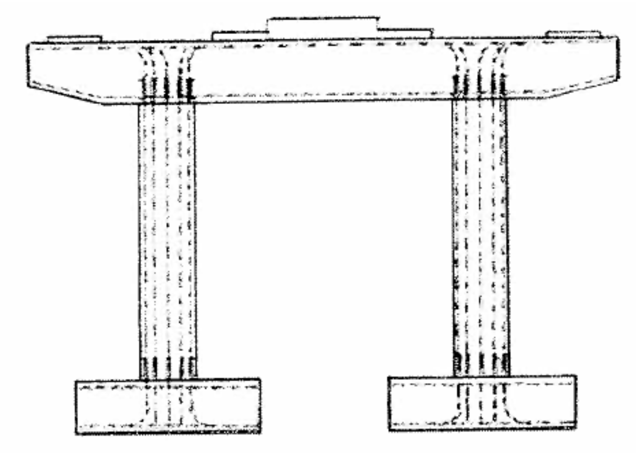

Figure 6: Precast Concrete Segmental Hammerhead Pier

2.3.2 Precast Concrete Segmental Bridge Piers

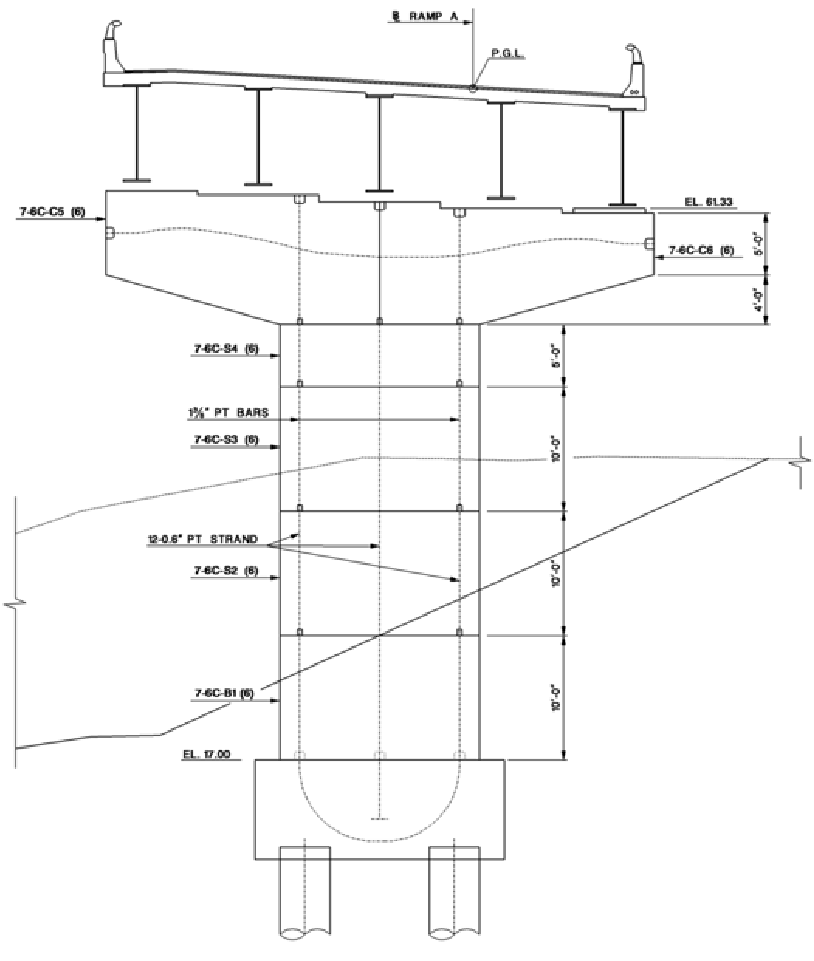

Figure 7: Precast Concrete Segmental Hammerhead Pier

Hammerhead type piers and straddle bent type piers are built with precast concrete segments stacked and post-tensioned together. The segments can be solid or hollow. Post-tensioning is done with pre-stressing rods and/or strands. The pre-stressing rods are anchored in the footing. The pre-stressing strands loop in and out of the footing. Rigid steel pipes are placed in the footing for this purpose. Figure 7 shows a precast concrete segmental hammerhead pier.

Straddle bent piers consist of two concrete columns supporting a long steel box type cap beam. They are suitable when there is no space available for the construction of bridge pier columns under the superstructure. This lack of space could be due to vehicular lanes, rail tracks, culverts or other objects.

2.3.3 Stub Abutments on Piles with Mechanically Stabilized Earth Walls

These stub abutments are supported on piles and wrapped around with Mechanically Stabilized Earth (MSE) Walls. Compared to conventional abutments, these can be built very rapidly and they are very aesthetically pleasing. Figure 8 such an abutment.

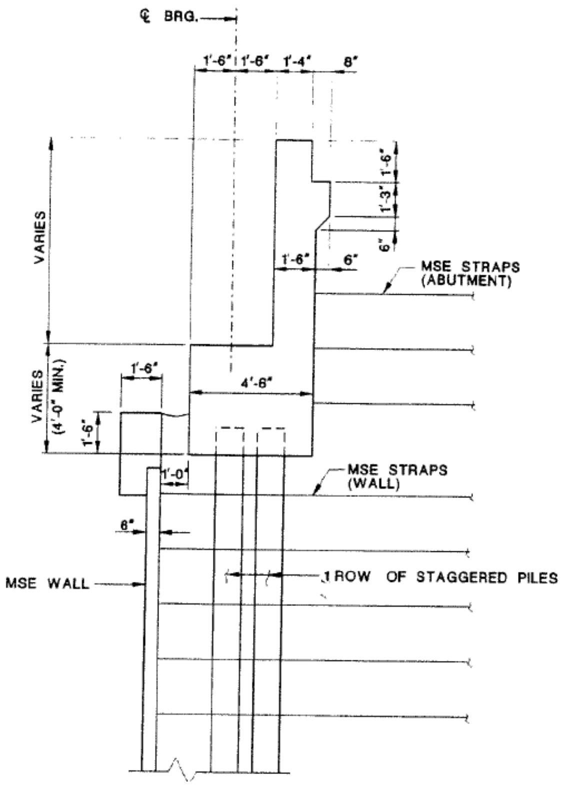

Figure 8: Stub Abutment on Piles with MSE Walls

2.4 Prefabricated Retaining Wall Systems

The conventional retaining walls are the cast-in-place concrete cantilever type and the gravity type retaining walls. However, with the advent of the Mechanically Stabilized Earth (MSE) Walls and the Modular Retaining Walls twenty five years ago, the wall construction has been revolutionized. Compared to the conventional construction, these proprietary walls are very cost effective, can be built very rapidly, and aesthetically pleasing. In this section two such wall types are presented.

2.4.1 Mechanically Stabilized Earth (MSE) Walls

MSE Wall is a soil-retaining system, employing either a strip or grid type, metallic, or polymeric tensile reinforcements in the soil mass, and a facing element that is either vertical or nearly vertical. Its strength and stability are derived from the frictional interaction between the granular backfill and the reinforcements, resulting in a permanent and predictable bond that creates a unique composite construction material. These walls are extensively used in bridge abutments and retaining walls among other applications. Figure 9 shows a schematic of an MSE Wall.

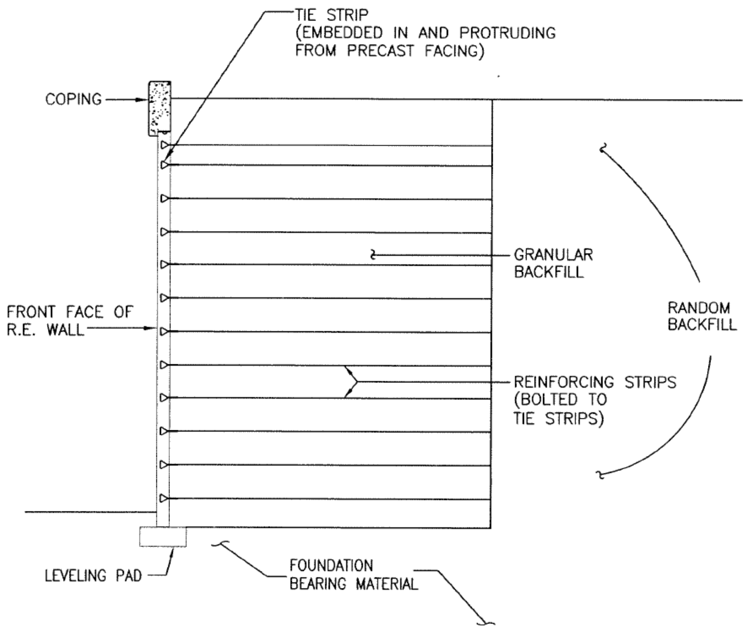

Figure 9: MSE Wall Schematic

2.4.2 T-Wall Retaining Wall System

The T-Wall retaining wall system is a gravity structure whose dimensions are bounded by a front plane formed by the facing panels and a back plane formed by the ends of the stems. The system stability is a function of the weight of the concrete units and the select backfill between the stems. The stems have to be long enough at each level to develop a cross section to resist overturning and sliding at that level and ensure soil/structure interaction. These walls are used in bridge abutments and retaining walls. Figure 10 shows a T-Wall schematic.

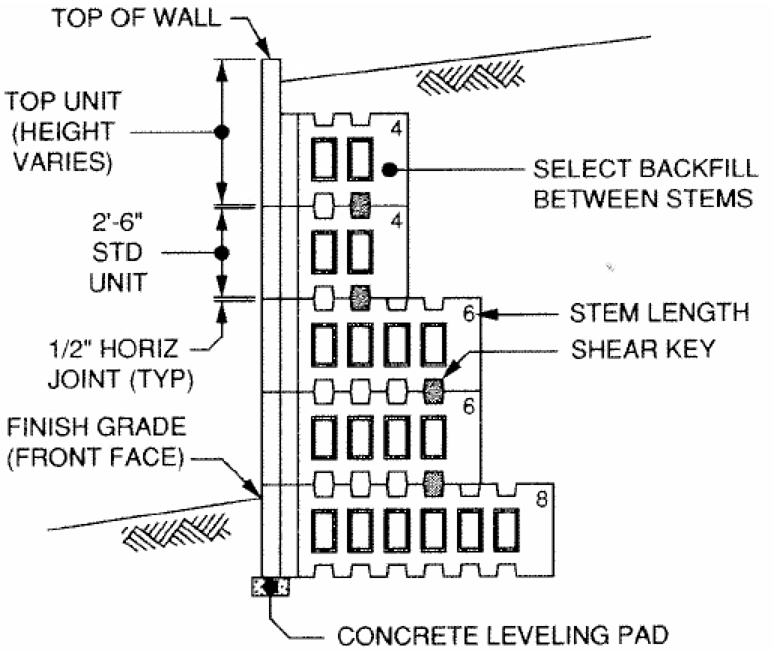

Figure 10: T-Wall Schematic

3. Conclusions and Recommendations

- The author has personal experience with most of the prefabricated elements discussed in this paper. He finds them extremely useful especially in congested areas where rapid construction is essential.
- The prefabricated elements discussed can be used in both new and rehabilitation projects.
- It is hoped that more Prefabricated Bridge Elements and Systems (PBES) will be used in bridge projects reducing disruption to traffic by expediting construction, lowering costs, minimizing environmental issues such as pollution, and enhancing safety and quality control.

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