

Reinforcing Steel Placement Handbook



Produced by

NEITC

Project Development Division
Reinforcing Steel Placement
Process Improvement Team

Reinforcement Steel Placement Process Improvement

Over the past several construction seasons, problems have become increasingly evident in the proper placement and maintainance of reinforcing steel in all phases of bridge and culvert construction. During the winter of 1998 and 1999, David Roeber, NEI TC Construction Engineer, assembled a process improvement team to review these problems. Dave also directed the team to put together a handbook to assist not only structures inspectors, but contractor's employees in understanding the reasoning behind the essential need for properly placing and maintaining reinforcing steel in bridges and culverts. The team was charged with completing their work prior to the 1999 construction.

The team included the following NEI TC and Bridge Design personnel:

Stanley Perkins, New Hampton RCE Office, Team Leader

Bob Beckman, New Hampton RCE Office

Gene Pavelka, Britt RCE Office

Mark Homan, Waterloo RCE Office

Clyde Mohorne, Waterloo RCE Office

Gregg Durbin, Office of Bridge Design

Dusty Rolando, Britt RCE Office

Dick Peterson, Facilitator

The team met weekly from late February through March. Following a brief "working in teams" training session during the first meeting, dug into their team's assignment. The NEI TC Reinforcing Steel Placement Process Improvement Team recommends adoption of this handbook to increase awareness of the importance of, and to ensure proper placement and maintenance of reinforcing steel prior to, during, and following placement of structural concrete.

In the pages that follow, you will find technical information on reinforcing steel placement and spacing, which the team found most enlightening. The team feels this explains, in ordinary terms, why proper placement and maintaining that placement is so important and critical to the structure's strength and durability. The team developed reinforcing steel checklists for all phases of structure's construction. The checklists also include Specification and Construction Manual references in a single location for your convenience.

The team encourages inspectors to read and understand the explanations on the critical placement of reinforcing steel and to use the checklists, on the work site, as reminders to review those most critical items, perhaps several times, which have recently and repeatedly been recognized as problems.

The team has assembled and reviewed the checklists and references. As each and all of you use this handbook, the team asks that you contact any team member if you find the handbook helpful, or not helpful, as you work through the coming construction season. The team needs your comments to assist in evaluating the effectiveness of the handbook.



Template used in a pier footing to assure proper spacing & alignment of column steel.



Proper spacing of vertical column bars.



Hoop bars in pier diaphragm are properly and adequately supported.



Vertical bars in a culvert wall are properly and adequately supported.



Two separate mats of reinforcing steel are independently supported in this slab for the RCB.



The vertical wall steel is properly secured to prevent it from drifting inward.

IMPORTANCE OF PROPER PLACEMENT OF REINFORCING STEEL

The improper placement of reinforcing steel can greatly reduce the strength and life of a structure and possibly lead to a structural failure. The failure of a structure does not necessarily mean the collapse of a structure. A structure fails when it can no longer be used in the manner in which it was intended. A bridge that deflects more than is tolerable by those using it is a failed structure. A culvert that allows water to flow in a path other than through the culvert is a failed structure. It is very uncommon for a bridge or a culvert to collapse under normal circumstances. Costly repairs and early replacement of structures, however, are too common and are often caused by improper reinforcing steel placement. It is hoped that a better understanding of the reasons for proper reinforcement placement and how to check for proper reinforcement will reduce the need for costly repairs and early replacements of structures. Below is a brief explanation of why different aspects of reinforcement placement are important. Some reinforcement inspection checklists for different structural elements are included at the end of this booklet.

CONCRETE COVER

When the reinforcing steel is placed with less concrete cover than required by design, the life of the reinforcing steel can be shortened due to corrosion from increased exposure to deicing materials and/or the elements. Corrosion of the reinforcing steel will cause an increase in the diameter of the steel, which will cause the concrete outside the steel to sometimes spall off and the concrete around the reinforcing steel to become debonded from the reinforcing steel. This debonding of the concrete from the reinforcing steel can reduce the strength of the structure by preventing the necessary interaction between the concrete and the reinforcing steel. Proper bonding between the reinforcing steel and the concrete can also be prevented by debris on the bar such as dirt, mud, oil, or corrosion when the concrete is poured around it.

Too much concrete cover, on the other hand, will reduce the strength of the structure. A common misconception is that if the minimum concrete cover is good then more concrete cover is even better. However, if the reinforcing steel is placed with more cover than designed for, the strength of the structure will be significantly reduced, as explained later in the **FLEXURAL DESIGN THEORY** section.

STRUCTURAL BACKGROUND

Concrete is strong in compression and weak in tension. Steel, however, has strength in both tension and compression. In a reinforced concrete structure, the two materials are used together in a manner that will make the best use of the strengths of each.

Consider the situation shown in figure 1. This is a common situation for a reinforced concrete section between two supports. This situation could represent a bridge slab supported between two beams or supported between an abutment and a pier, or it could represent a culvert slab, wall, or floor.

The reinforcing closest to the surface of the concrete is usually the main reinforcing and runs from one support to the other. The main reinforcing can be either at the top of the section or the bottom of the section depending on how the section is designed to be loaded. The function of the reinforcing that is placed perpendicular to the main reinforcing is to distribute stresses between the main reinforcing and help control cracking of the concrete.

The location of the main reinforcing steel depends on the direction of flexure of the structure. The main reinforcing in a reinforced concrete box culvert wall is the vertical reinforcing steel on both sides of the wall. The main reinforcing in a single barrel reinforced concrete box culvert slab is the bottom transverse reinforcing steel. The main reinforcing in a bridge slab supported by beams is both the top and the bottom transverse reinforcing steel.

FLEXURAL DESIGN THEORY

Somewhere between the main reinforcing and the opposite edge of the concrete is an imaginary line called the neutral axis, (see figure 2). Material on one side of the neutral axis is in compression and material on the other side of the neutral axis (the side containing the main reinforcing) is in tension. The neutral axis has neither compression nor tension since it is the point at which the stress changes from tension to compression.

Consider the situation shown in figure 1. The main reinforcing in this situation would be the lowest layer of reinforcing bars. Notice that these reinforcing bars run from one support to the other. When the section is loaded as shown in figure 2, the section flexes downward. When the section flexes downward the concrete and reinforcing steel above the neutral axis are in compression and at the same time, the concrete and reinforcing steel below the neutral axis are in tension. As the section below the neutral axis is stretched by the tensile force, the steel and concrete stretch together at the same rate due to the bond between the reinforcing steel and concrete. During this stretching, the reinforcing steel elongates and retains its tensile strength. The concrete

in the tension zone however, cracks and contributes no tensile strength to the structure (see figure 3). Therefore, the concrete below the neutral axis is disregarded when determining the flexural strength of the structure.

The theoretical design section shown in figure 4 is a cross section of the structure looking along the main reinforcing showing only the materials considered to be contributing to the strength of the structure. The dashed lines in figure 4 represent the area of cracked concrete that does not contribute to the strength of the structure. The steel in the compression zone does not significantly increase the compressive strength of the concrete and therefore the area above the neutral axis is assumed to be solid concrete for design purposes.

Placing the reinforcing steel with more than the design cover causes the neutral axis to be shifted higher in the section, which reduces the area of concrete that is in compression and increases the cracked area of concrete in tension. **This decrease in useful concrete and increase in useless concrete greatly reduces the strength of the structure.**

LAP LENGTH

The design lap length is usually a minimum length required to transfer stress from one bar to another. Consider for example, the longitudinal steel in the slab of a bridge or in a culvert, or the vertical steel in the back face of a culvert wall. It would be ideal to make these bars one continuous bar, this however would be impractical due to difficulties in transporting and handling the steel. In order to achieve the same effect as having one continuous bar, the design will call for shorter bars and minimum lap lengths. If the actual lap length is less than the required lap length, the stress may not be transferred to the other bar, which could cause a failure in the structure at that lap location.

DEVELOPMENT LENGTH

The development length is often shown on the plans as a minimum embedment length. The purpose of the development length is to anchor the reinforcing bars beyond the area where the strength of the bars is needed. Without the required development length, the reinforcing bar would pull out of the concrete surrounding it and the structure could fail. A typical example of this situation would be the top transverse reinforcing bars in the cantilevered section of a bridge slab outside the exterior beam of a bridge. The critical section of the slab is just outside the outside edge of the beam supporting the slab. The reinforcing bars must extend into the slab beyond the critical section for a required length. If the reinforcing bars do not extend beyond the critical section sufficiently, they will be pulled out and the structure will fail.

BAR SPACING AND BAR SIZE

The amount of reinforcing steel in the tension area of the structure also has a large impact on the strength of the structure. Both the spacing and the size of the reinforcing bars control the amount of steel in the tension area. The impacts to flexural strength from deviations in bar spacing and bar size are shown in figure 5.

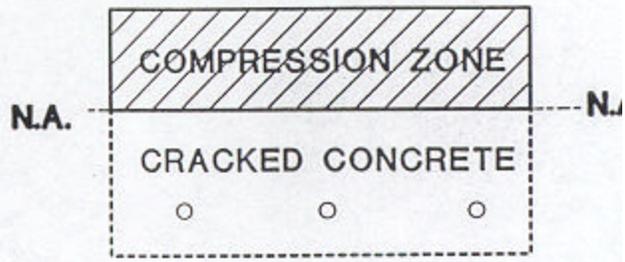
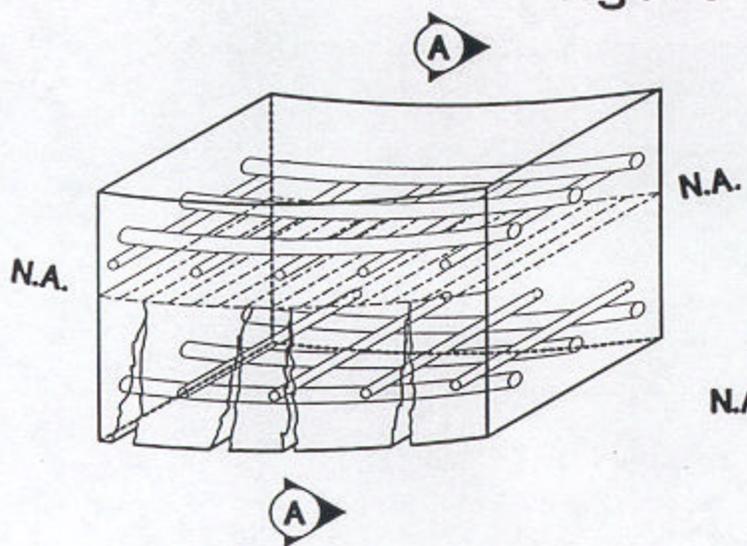
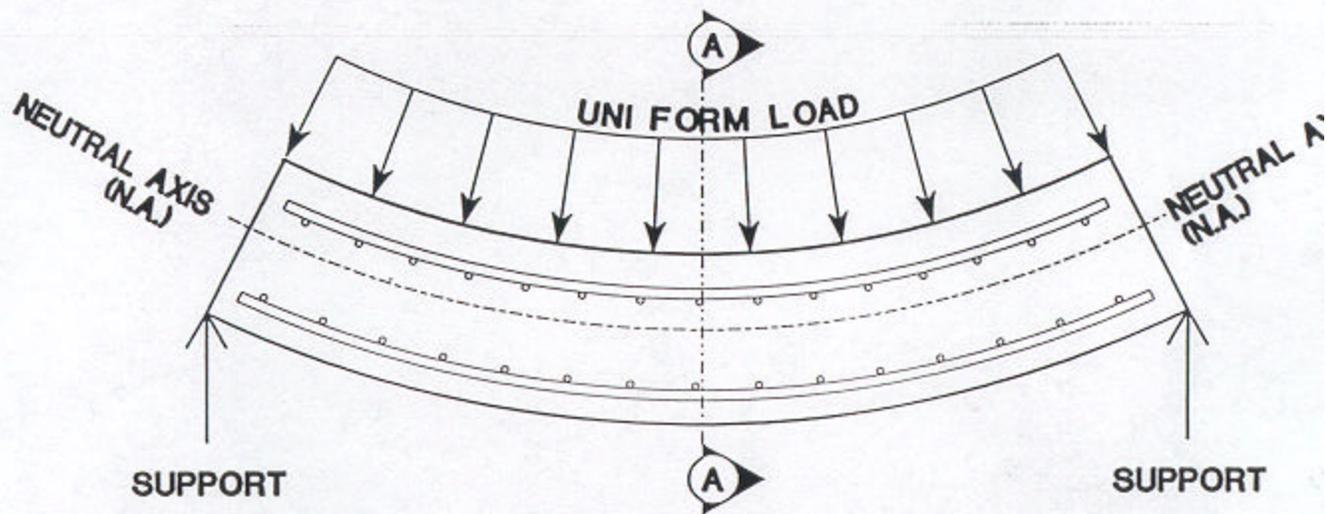
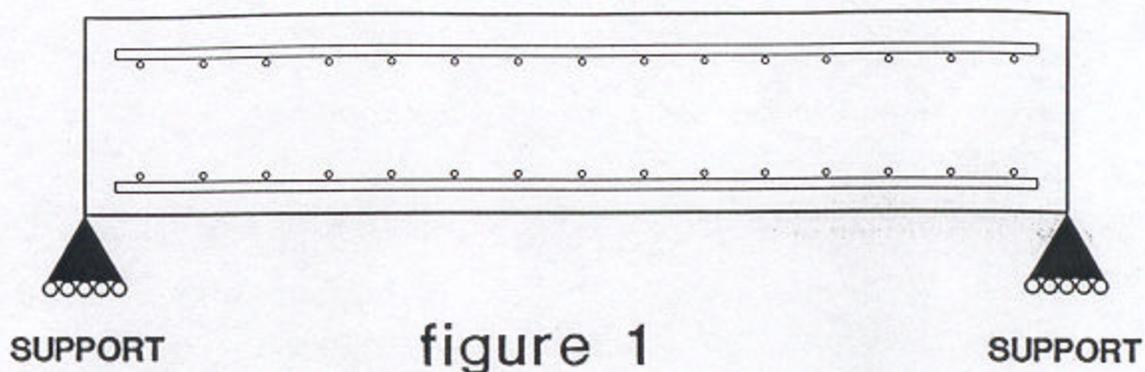
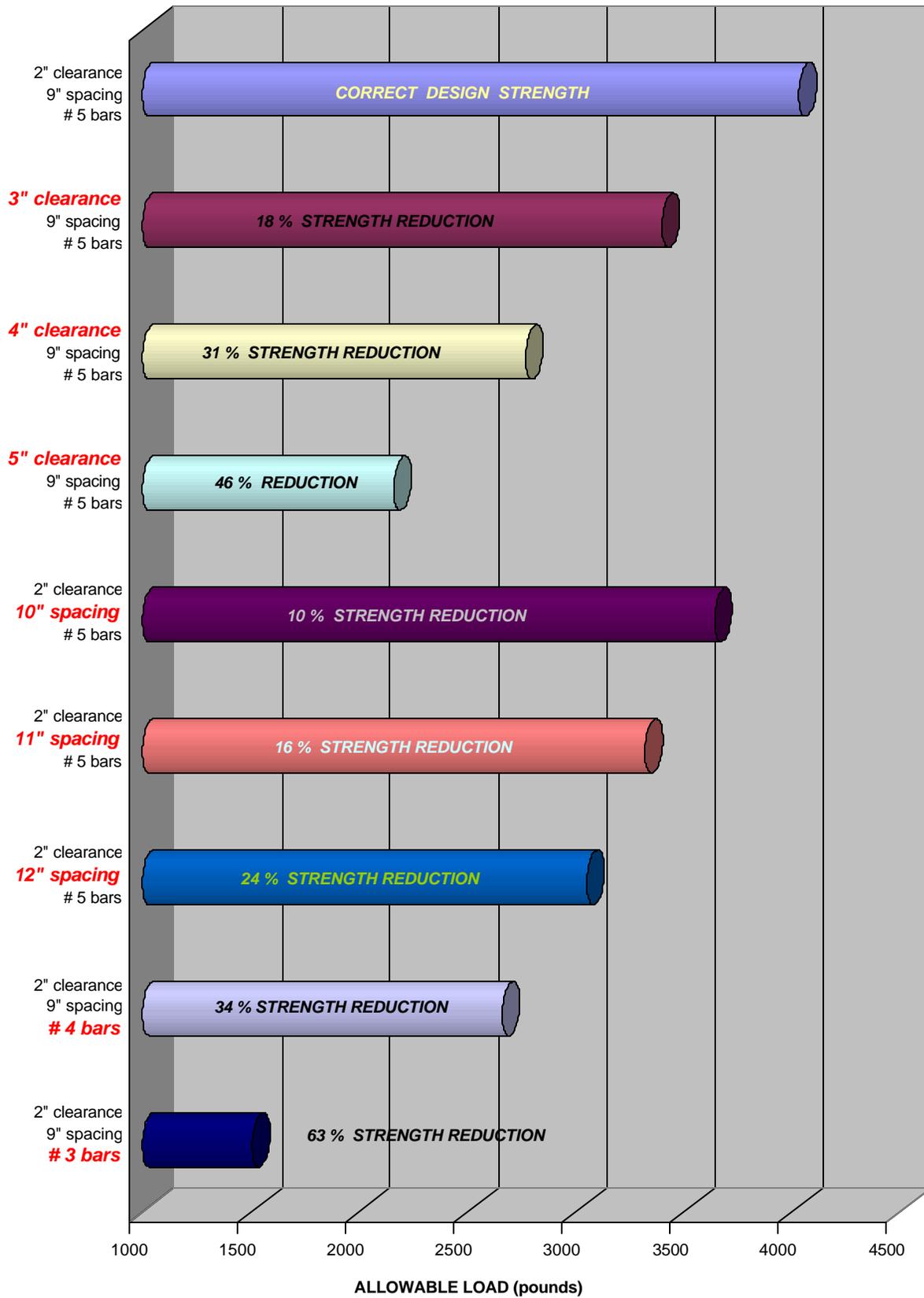


figure 4



Reinforcing Steel Check List

Abutment Footing

<u>Items To Check</u>		<u>Reference Areas</u>		
		Project Documents	Specifications (Check Proper Supplementals)	Construction Manual
<input type="checkbox"/>	Number of Bars	Plans		
<input type="checkbox"/>	Spacing Before and After Concrete Placement	Plans	Section 2404 Article 2404.06	Chapter 11 Section 11.40
<input type="checkbox"/>	End and Side Clearances	Plans	Section 2404 Article 2404.06	Chapter 11 Section 11.40
<input type="checkbox"/>	Top and Bottom Clearances	Plans	Section 2404 Article 2404.06	Chapter 11 Section 11.40
<input type="checkbox"/>	Bar Sizes	Plans		
<input type="checkbox"/>	Assure Bars Are Free Of Dirt, Oil, Rust, Paint, Etc.		Section 2404 Article 2404.03	
<input type="checkbox"/>	Placement and Adequacy Of Supports		Section 2404 Article 2404.07	
<input type="checkbox"/>	Bar Junctions Are Adequately Tied		Section 2404 Article 2404.06	
<input type="checkbox"/>	The Vertical Bar Embedments for Proper Lap Length	Plans		
<input type="checkbox"/>	Assure the Piling Spirals Are Securely Placed	Plans		
<input type="checkbox"/>	Epoxy Steel for Possible Repair's		Section 4151 Article 4151.03 B 10	
<input type="checkbox"/>	Horizontal Bars for Minimum Lap	Plans	Section 2404 Article 2404.08	Chapter 11 Section 11.40

Notes : Vertical bars that protrude from the footing into the abutment diaphragm or the abutment backwall must be tied in the abutment footing to insure proper edge clearance in the abutment diaphragm or the abutment backwall.

Epoxy coated reinforcing steel shall be held in place with epoxy or plastic coated bar supports and epoxy or plastic coated tie wires as described in Section 2404 Article 2404.07 of the Spec Book and Chapter 11 Paragraph 11.42 of the Construction Manual.

Reinforcing Steel Check List

Abutment Backwalls & Diaphragms

Items To Check

Reference Areas

		Project Document	Specifications (Check Proper Supplementals)	Construction Manual
<input type="checkbox"/>	Number of Bar's	Plans		
<input type="checkbox"/>	Spacing Before and After Concrete Placement	Plans	Section 2404 Article 2404.06	Chapter II Section 11.40
<input type="checkbox"/>	End and Side Clearances	Plans	Section 2404 Article 2404.06	Chapter II Section 11.40
<input type="checkbox"/>	Top Clearances	Plans	Section 2404 Article 2404.06	Chapter II Section 11.40
<input type="checkbox"/>	Bar Sizes	Plans		
<input type="checkbox"/>	Assure Bars Are Free Of Dirt, Oil, Rust, Paint, Etc.		Section 2404 Article 2404.03	
<input type="checkbox"/>	Placement and Adequacy Of Supports		Section 2404 Article 2404.07	
<input type="checkbox"/>	Bar Junctions Are Adequately Tied		Section 2404 Article 2404.06	
<input type="checkbox"/>	Epoxy Steel For Needed Repairs		Section 4151 Article 4151.03 B 10	Chapter 11 Section 11.42

Notes : Epoxy coated reinforcing steel shall be held in place with epoxy or plastic coated bar supports and epoxy or plastic coated tie wires as described in Section 2404 Article 2404.07 of the Spec Book and Chapter 11 Paragraph 11.42 of the Construction Manual.

Reinforcing Steel Check List

Pier Footing

	<u>Items To Check</u>	Project Documents	<u>Reference Areas</u> Specifications (Check proper Supplementals)	Construction Manual
<input type="checkbox"/>	Number of Bars	Plans		
<input type="checkbox"/>	Spacing Before and After Concrete Placement	Plans	Section 2404 Article 2404.06	Chapter I I Section 11.40
<input type="checkbox"/>	End and Side Clearances	Plans	Section 2404 Article 2404.06	Chapter I I Section 11.40
<input type="checkbox"/>	Top and Bottom Clearances	Plans	Section 2404 Article 2404.06	Chapter 11 Section 11.40
<input type="checkbox"/>	Bar Sizes	Plans		
<input type="checkbox"/>	Assure Bars Are Free Of Dirt, Oil, Rust, Paint, Etc.		Section 2404 Article 2404.03	
<input type="checkbox"/>	Placement and Adequacy Of Supports		Section 2404 Article 2404.07	
<input type="checkbox"/>	Vertical Bar Embedment To Assure Proper Lap Length	Plans		
<input type="checkbox"/>	Bar Junctions Are Adequately Tied		Section 2404 Article 2404.06	

NOTES :

Concrete block inserts, bricks, stones, wood blocks, wood stakes, & similar materials shall not be used for supporting reinforcement if the manner of their use is such that these materials are likely to become embedded in the concrete as stated in Section 2404 Article 2404.07 in the Spec Book.

Where two or more separate mats of reinforcing steel are required, each mat shall be independently supported by an approved support system as described in Section 2404 Article 2404.07 in the Spec Book.

Reinforcing Steel Check List

Pier Column

<u>Items To Check</u>		<u>Reference Areas</u>		
		Project Documents	Specifications (Check Proper Supplementals)	Construction Manual
<input type="checkbox"/>	Number of Bars	Plans		
<input type="checkbox"/>	Spacing Before and After Concrete Placement	Plans	Section 2404 Article 2404.06	Chapter 11 Section 11.40
<input type="checkbox"/>	Side Clearances	Plans	Section 2404 Article 2404.06	Chapter 11 Section 11.40
<input type="checkbox"/>	Check Vertical Bars For Minimum Length of Protrusion Into Cap	Plans		
<input type="checkbox"/>	Bar Sizes	Plans		
<input type="checkbox"/>	Assure Bars Are Free Of Dirt, Oil, Rust, Paint, Etc.		Section 2404 Article 2404.03	
<input type="checkbox"/>	Placement and Adequacy Of Supports		Section 2404 Article 2404.07	
<input type="checkbox"/>	Check the Diameter of the Hoop Diameter	Plans		
<input type="checkbox"/>	Bar Junctions Are Adequately Tied		Section 2404 Article 2404.06	

NOTES:

It is usually advisable that the contractor wire bar chairs to the outside of the hoop bars to insure minimum bar clearance.

Reinforcing Steel Check List

Pier Cap

<u>Items To Check</u>		<u>Reference Areas</u>		
		Project Documents	Specifications Check Proper Supplementals	Construction Manual
<input type="checkbox"/>	Number of Bars	Plans		
<input type="checkbox"/>	Spacing Before and After Concrete Placement	Plans	Section 2404 Article 2404.06	Chapter 11 Section 11.40
<input type="checkbox"/>	End and Side Clearances	Plans	Section 2404 Article 2404.06	Chapter 11 Section 11.40
<input type="checkbox"/>	Top and Bottom Clearances	Plans	Section 2404 Article 2404.06	Chapter 11 Section 11.40
<input type="checkbox"/>	Bar Sizes	Plans		
<input type="checkbox"/>	Assure Bars Are Free Of Dirt, Oil, Rust, Paint, Etc.		Section 2404 Article 2404.03	
<input type="checkbox"/>	Placement and Adequacy Of Supports		Section 2404 Article 2404.07	
<input type="checkbox"/>	Bar Junctions Are Adequately Tied		Section 2404 Article 2404.06	

NOTES :

The Contractor should place bar chairs between the bars and the side and bottom forms to assure minimum bar clearance.

Reinforcing Steel Check List

Intermediate & Pier Diaphragms

<u>Items To Check</u>		<u>Reference Areas</u>		
		Project Documents	Specifications (Check Proper Supplementals)	Construction Manual
<input type="checkbox"/>	Number of Bars	Plans		
<input type="checkbox"/>	Spacing Before and After Concrete Placement	Plans	Section 2404 Article 2404.06	Chapter II Section 11.40
<input type="checkbox"/>	End and Side Clearances	Plans	Section 2404 Article 2404.06	Chapter 11 Section 11.40
<input type="checkbox"/>	Top Clearances	Plans	Section 2404 Article 2404.06	Chapter 11 Section 11.40
<input type="checkbox"/>	Bar Sizes	Plans		
<input type="checkbox"/>	Assure Bars Are Free Of Dirt, Oil, Rust, Paint, Etc.		Section 2404 Article 2404.03	
<input type="checkbox"/>	Placement and Adequacy Of Supports		Section 2404 Article 2404.07	
<input type="checkbox"/>	Bar Junctions Are Adequately Tied		Section 2404 Article 2404.06	

Notes :

The tails of the hoop bars should extend into the deck, between the mats of deck steel, as per the plan detail.

In addition to providing an approved support system to maintain the minimum clearance, it will also be necessary to provide restraint to the vertical steel to prevent it from drifting inward.

Reinforcing Steel Check List

Bridge Decks

<u>Items To Check</u>		<u>Reference Areas</u>		
		Project Documents	Specifications (Check Proper Supplementals)	Construction Manual
<input type="checkbox"/>	Number of Bars	Plans		
<input type="checkbox"/>	Spacing Before and After Concrete Placement	Plans	Section 2404 Article 2404.06	Chapter 11 Section 11.41
<input type="checkbox"/>	End and Side Clearances	Plans	Section 2404 Article 2404.06	Chapter 11 Section 11.41
<input type="checkbox"/>	Top and Bottom Clearances	Plans	Section 2404 Article 2404.06	Chapter 11 Section 11.41
<input type="checkbox"/>	Bar Sizes	Plans		
<input type="checkbox"/>	Assure Bars Are Free Of Dirt, Oil, Rust, Paint, Etc.		Section 2404 Article 2404.03	
<input type="checkbox"/>	Placement and Adequacy Of Supports		Section 2404 Article 2404.07 & Section 2412 Article 2412.04	
<input type="checkbox"/>	Bar Junctions Are Adequately Tied		Section 2412 Article 2412.04	
<input type="checkbox"/>	Epoxy Steel For Needed Repairs		Section 4151 Article 4151.03 B 10	Chapter 11 Section 11.42
<input type="checkbox"/>	Check The Vertical Protrusion and Alignment Of The Barrier Rail Hoops	Plans		

Notes :

Epoxy coated reinforcing steel shall be held in place with epoxy of plastic coated bar supports and epoxy or plastic **coated tie wires**. This is pointed out in Section 2404 Article 2404.07 of the Spec Book and in Chapter 11 Paragraph 11.42 B of the Construction Manual.

Where two or more separate mats of reinforcing steel are required, each mat shall be independently supported by an approved support system as described in Section 2404 Article 2404.07 In the Spec Book.

The top mat must be checked for clearance before and after concrete placement as described in Section 2412 Article 2412.04 of the spec book and in Chapter 11 Paragraph 11.41 of the Construction Manual.

The top mat of deck reinforcement shall be held securely in place as described in Section 2412 Article 2412.04 of the Spec Book and in Chapter 11 Paragraph 11.41.

Make sure the mats of the deck reinforcing steel are adequately and properly supported in the area outside the exterior beams and at the abutment diaphragms by an approved support system.

Reinforcing Steel Check List

Barrier Rails

<u>Items To Check</u>		Project Documents	<u>Reference Areas</u> Specifications (Check Proper Supplementals)	Construction Manual
<input type="checkbox"/>	Number of Bars	Plans		
<input type="checkbox"/>	Spacing Before and After Concrete Placement	Plans	Section 2404 Article 2404.06	Chapter 11 Section 11.40
<input type="checkbox"/>	End and Side Clearances	Plans	Section 2404 Article 2404.06	Chapter 11 Section 11.40
<input type="checkbox"/>	Top and Bottom Clearances	Plans	Section 2404 Article 2404.06	Chapter 11 Section 11.40
<input type="checkbox"/>	Bar Sizes	Plans		
<input type="checkbox"/>	Assure Bar's Are Free Of Dirt, Oil, Rust, Paint, Etc.		Section 2404 Article 2404.03	
<input type="checkbox"/>	Placement and Adequacy Of Supports		Section 2404 Article 2404.07	
<input type="checkbox"/>	Bar Junctions Are Adequately Tied		Section 2404 Article 2404.06	
<input type="checkbox"/>	Epoxy Steel For Needed Repairs		Section 4151 Article 4151.03 B 10	Chapter 11 Section 11.42

Notes : Epoxy coated reinforcing steel shall be held in place with epoxy of plastic coated bar supports and epoxy or plastic coated tie wires as described in Section 2404 Article 2404.07 of the Spec Book and Chapter 11 Paragraph 11.42 of the Construction Manual.

Reinforcing Steel Check List

Culvert Footing

<u>Items To Check</u>		Project Documents	<u>Reference Areas</u> Specifications (Check Proper Supplementals)	Construction Manual
<input type="checkbox"/>	Number of Bars	Culvert Standards		
<input type="checkbox"/>	Spacing Before and After Concrete Placement	Culvert Standards	Section 2404 Article 2404.06	Chapter 11 Section 11.82
<input type="checkbox"/>	End and Side Clearances	Culvert Standards	Section 2404 Article 2404.06	Chapter 11 Section 11.82
<input type="checkbox"/>	Top and Bottom Clearances	Culvert Standards	Section 2404 Article 2404.06	Chapter I I Section 11.82
<input type="checkbox"/>	Bar Sizes	Culvert Standards		
<input type="checkbox"/>	Assure Bars Are Free Of Dirt, Oil, Rust, Paint, Etc.		Section 2404 Article 2404.03	
<input type="checkbox"/>	Placement and Adequacy Of Supports		Section 2404 Article 2404.07	
<input type="checkbox"/>	Bar Junctions Are Adequately Tied		Section 2404 Article 2404.06	
<input type="checkbox"/>	The Length of the Vertical Bars Protruding into The Barrel Section	Culvert Standards		
<input type="checkbox"/>	Assure The Lap Lengths Are At The Minimum Lengths	Culvert Standards		

Notes : Concrete block inserts, bricks, stones, wood blocks, wood stakes, & similar materials shall not be used for supporting reinforcement if the manner of their use is such that these materials are likely to become embedded in the concrete as stated in Section 2404 Article 2404.07 in the Spec Book.

Where two or more separate mats of reinforcing steel are required, each mat shall be independently supported by an approved support system as described in Section 2404 Article 2404.07 In the Spec Book.

Culvert Standards do not always list the number of bars required due to differences in section lengths. You have to use the spacing of the bars & the length of the section to calculate the number of bars required.

In order to know the dimensions & quantities of bars in the barrel sections, you have to check the plan notes for the anticipated fill.

The Contractor may use the keyway to space vertical bars *ONLY* if the proper side clearances are maintained.

Reinforcing Steel Check List

Culvert Barrel

<u>Items To Check</u>		<u>Reference Areas</u>		
		Project Documents	Specifications (Check Proper Supplementals)	Construction Manual
<input type="checkbox"/>	Number of Bars	Culvert Standards		
<input type="checkbox"/>	Spacing Before and After Concrete Placement	Culvert Standards	Section 2404 Article 2404.06	Chapter II Section 11.82
<input type="checkbox"/>	End and Side Clearances	Culvert Standards	Section 2404 Article 2404.06	Chapter 11 Section 11.82
<input type="checkbox"/>	Top and Bottom Clearances	Culvert Standards	Section 2404 Article 2404.06	Chapter II Section 11.82
<input type="checkbox"/>	Bar Sizes	Culvert Standards		
<input type="checkbox"/>	Assure Bars Are Free Of Dirt, Oil, Rust, Paint, Etc.		Section 2404 Article 2404.03	
<input type="checkbox"/>	Placement and Adequacy Of Supports		Section 2404 Article 2404.07	
<input type="checkbox"/>	Bar Junctions Are Adequately Tied		Section 2404 Article 2404.06	
<input type="checkbox"/>	If Required, Assure The Lap Lengths of the Wall Bars Are At The Minimum Lengths	Culvert Standards	Section 2404 Article 2404.08	Chapter 11 Section 11.82

Notes :

Where two or more separate mats of reinforcing steel are required, each mat shall be independently supported by an approved support system as described in Section 2404 Article 2404.07 of the Spec Book.

It is usually advisable that **the Contractor tie bar** chairs to the outside wall bars to insure minimum bar clearance. It will be necessary for the Contractor to provide some method of restraining the vertical bar mats to prevent them from drifting inward. It will probably be necessary to provide additional restraints along the vertical bars, as well as the top and bottom, depending on the height of the wall and flexibility of the bars.

Culvert Standards do not always list the number of bars required due to the difference in section lengths. You have to use the spacing of the bars & the length of the section to calculate the number of bars.

In order to know the dimensions & quantities of bars in the barrel sections you have to check the plan notes for the anticipated fill.