STRUCTURES

Bridge Management

1988 Graber Bill
The Bill was introduced after the collapse of the Schoharie Bridge and is an effort to reduce (or eliminate) the vulnerability of bridges, to failure or collapse, thru a comprehensive **B**ridge **M**anagement **S**ystem (**BMS**).

Bridge Components

SUPERSTRUCTURE: *those components of a bridge which support the deck, and the loads applied to the deck, across the span to the bridge support.*

> **Bearings:** the element acting as an interface between superstructure and substructure to transmit load, also allows rotation due to deflection, and allows movement for thermal expansion and contractions.
> **Deck:** the component of a bridge to which live load is directly applied. The deck provides a smooth and safe riding surface for the traffic utilizing the bridge.
> **Main Member:** that component of a bridge which supports the bridge deck. (some common types include: multi-girder, multiple pipe, box culvert, thru-truss, pony-truss, deck-truss, suspension).

SUBSTRUCTURE: *that portion of the bridge that transfers load from the superstructure to the soil or rock foundation, includes all elements supporting that superstructure.*

> **Abutments:** a substructure unit located at the ends of the bridge, function being to provide end support for the bridge and to retain the approach embankment.
> **Piers:** an intermediate substructure unit located between the ends of the bridge, function being to support the bridge at intermediate intervals with minimal obstruction to the flow of traffic or water.
> **Wingwalls:** walls on either side of an abutment which enclose the approach fill, generally considered a retaining wall as they are designed to maintain a difference in ground surface elevation on two sides of the wall.
> **Foundation** (footings and piles): mechanism for spreading loads to the supporting soil or rock.

INSPECTION

NYSDOT BRIDGE INSPECTION MANUAL (1997), Appendix "F" is the UNIFORM CODE OF BRIDGE INSPECTION, that sets forth the standards for any publicly owned, operated, or maintained bridge, open to vehicular traffic. The definition of a **BRIDGE** is: *A structure (including supports), erected over a depression, obstruction (such as water, etc.), having a track or passageway for carrying public traffic, and measured along the centerline of the roadway, has an opening between supports of* ***20'-0" or more*** *(may include multiple culvert pipes).*

The **NYSDOT BRIDGE INSPECTION MANUAL** (1997) sets inspection standards to try to maintain uniformity of application, it gives a full and detailed reference to the bridge inspection processes (what you are looking for and where to find it) and applications (sets a condition scale, including rating examples and minimum standards for the bridges).

The condition scale allows the bridge to be rated according to *condition* and *functionality*:

"9" is for unknown (hidden or buried)
"8" is for not applicable items
"7" is for like new condition
"5" is for items with minor deterioration
"3" is for items with severe deterioration or not functioning as originally designed
"1" is for items in failure or total deterioration
"2", "4", "6" are used to shade ratings
(Note" Federal guidelines use a 1 to 9 scale vs. NYSDOT 1 to 7)

PERFORMING BRIDGE INSPECTIONS

The following information is a guide to performing bridge inspections as required by *New York State's Uniform Code of Bridge Inspection*. It is used when inspecting any publicly owned, operated or maintained bridge in New York State that is open to vehicular traffic. There are a small number of bridges that do not carry traffic but are routinely inspected and have their data entered in the New York State Bridge Inventory and Inspection System (now BDMS, formerly BIIS). This information should also be used when inspecting these non-mandated bridges.

For questions related to material behavior, mechanics or fundamentals of bridge inspection, consult the latest edition of the federal *Bridge Inspector's Training Manual/90*.

Types and Required Intervals of Inspections

Four types of inspections are performed in New York State:

1 - Biennial. Required for all highway bridges every two years and the standard and most common type of inspection. For new or reconstructed bridges, a biennial inspection is required within 60 days of fully opening to traffic or upon contract acceptance, whichever comes first.

2 - Interim. Some structures need to be inspected annually because of one or more deficiencies. Interim inspections are performed during the calendar year between the required biennial inspections, and are required if one or more of the following conditions exist:

- General recommendation (determined by inspector) of 3 or less.
- Condition rating (weighted average of individual item ratings) of 3.00 or less.
- Presence of an active or inactive Red Flag, or active Yellow Flag.
- Posting for any load other than R-permit restriction.

4 – None (under contract). This is for bridges closed to all traffic due to reconstruction. A biennial inspection must be performed within 60 days of reopening. A temporary detour bridge that may be carrying traffic during reconstruction is also covered by the Type 4 inspection; temporary structures are the contractor's responsibility and do not get biennial or interim inspections.

5 – Special. Performed to address maintenance and/or inspection concerns unique to a particular bridge. These inspections are not entered into the database, so regular biennial inspections are still required. For large or unusually complex structures, a Type 5 inspection may be performed instead of an interim inspection with written approval of the Deputy Chief Engineer, Structures.

Note: Type 3 inspections are no longer used with BDMS. Type 3 inspections were previously identified in the *Bridge Inspection Manual – 82* as in-depth inspections. In-depth inspections are normally done before beginning design for rehabilitation or replacement. In the event that a biennial or interim inspection is to be performed in addition to an in-depth inspection, the inspection must be identified as either a Type 1 (biennial) or Type 2 (interim) inspection, with all documentation required by this manual.

Intervals between biennial inspections, for bridges not requiring interim inspections, must be generally no greater than 26 months. Bridges requiring interim inspections should be scheduled so that the interval between successive inspections is not generally greater than 13 months. These intervals may be exceeded only under extenuating circumstances such as inspecting during low water to avoid a diving inspection, seasonal traffic peaks that preclude use of access equipment, etc.

An inspection team consisting of <u>at least</u> a **Team Leader** (a P.E. with 3 years bridge experience), and an **Assistant Team Leader** (a combination of B.S. and/or up to 3 years bridge experience), goes to the bridge with sketches or a set of plans. Any substantial alterations of a bridge built after 6/1/89 must have a certified set of plans per UNIFORM CODE OF BRIDGE INSPECTION.

The inspection team:

a). Verifies that actual field conditions are the same as indicated on the plans.
b). Verifies that the bridge inventory matches the actual field conditions.
c). Checks for any repairs or improvements that have been made.
d). Documents any and all deterioration.

e). Rates for condition and functionality, all the bridge components.
f). Verifies Load Rating Input Forms.
g). Verifies **BSA**'s vulnerability assessments and ratings.
h). Flags any unsafe conditions.

BRIDGE SAFETY ASSURANCE (BSA)

At this time, we should stop and discuss **NYSDOT B**ridge **S**afety **A**ssurance (BSA) Program, a systematic program to reduce the vulnerability of the state's bridges for all potentially significant modes of failure by:

1). Identifying the areas of greatest vulnerability
2). Implementing a proactive system to evaluate all state bridges and taking corrective action based on urgency of need.

The ***BSA*** *identification phase* determined the following 6 modes were the most significant in terms of the potential damage they can cause to highway bridges:

Hydraulic: Accounts for over 60% of all bridge failures according to publication #FHWA-SA-96-036 (10/98), "Scour monitoring and Instrumentation". The goal of this program is to identify vulnerability to failure caused by scour or hydraulic forces, and implement measures, such as flood watches, interim retrofits, or capital improvements to reduce vulnerability.
Overload: The goal of this program is to identify relative vulnerability to overload vehicles, so that necessary vulnerability reduction measures can be implemented in an efficient and effective manner. Load ratings are used to insure that weight restrictions are in place if necessary.
Steel Details: The goal of this program is to identify vulnerability to failure caused by steel deterioration, undesirable fatigue related steel details, or any combination of both, so that measures such as: more frequent inspections, interim retrofits, or capital improvements can be taken to reduce the bridge vulnerability.
Collision: The goal of this program is to identify the relative vulnerability of failure due to collision impact damage, so that any necessary vulnerability reduction measures can be implemented in an efficient and effective manner.
Concrete Details: The goal of this program is to identify the vulnerability of failure, caused by undesirable concrete details.
Earthquake: The goal of this program is to identify and reduce a bridges vulnerability to failure caused by an earthquake, as part of an evaluation and retrofit program.

Each assessment is given a **V**ulnerability **R**ating (**VR**). (The lowest of the failure modes control).
VR 1 = Safety Priority } – high vulnerability – need for immediate evaluation and and appropriate action.

VR 2 = Safety Program } – in need of evaluation and appropriate action within 1-2 years.
VR 3 = Capital Program } – action is warranted.
VR 4 = Inspection Program } – concerns are sufficiently addressed.
VR 5 = No Action.
VR 6 = Not Applicable.

These Vulnerability Assessments, used in conjunction with each other, are providing a complete understanding of the vulnerability of a bridge. For bridges with a **V**ulnerability **R**ating of 1 or 2, Section 232.4 of **HIGHWAY LAW**, and Section 165.11 of UNIFORM CODE OF BRIDGE INSPECTION requires that a **S**tructural **I**ntegrity **E**valuation **(SIE)**, *and* appropriate action be taken.

The scope of an **SIE** shall include the following (as appropriate) to determine the safety and integrity of the bridge:

A). Review design and design code changes, "as-builts", contract documents, history, structural alternations, rehabilitation, and maintenance repairs.
B). Review Vulnerability Assessments, do an in-depth engineering analysis for the appropriate failure modes. If bridge is over water, do a scour and hydraulic analysis.
C). Do or review a Level I Load Rating.
D). Do an evaluation of deterioration (from inspection reports), and modifications to structure.
E). Do a life cycle projection of scope and estimated cost of maintenance, repair, and/or rehab.

The UNIFORM CODE OF BRIDGE INSPECTION requires an Engineer (a P.E. with 3 years bridge experience) to supervise the preparation, and sign all SIE reports.

LOAD RATINGS

The UNIFORM CODE OF BRIDGE INSPECTION has set down guidelines for Load Ratings, requiring an Engineer, (a P.E. with 3 years bridge experience), responsible for directing, supervising, and signing all structural capacity load rating calculations.

A bridge load rating is used to determine the *usable live load capacity,* based on the judgment of the engineer using either load factor analysis or allowable stress analysis.

Each structural member has a load capacity unique to itself.
The most critical load ratings are the ratings given.
Load ratings generally use the following equation:

$$\frac{\text{Allowable load} - \text{dead load}}{\text{Rating vehicle live load plus impact}} \times \text{rating vehicle weight (tons).}$$

(Ratings expressed in tonnage)

Ratings are defined by AASHTO configurations of "H", and "HS" and expressed as tonnage.

All new bridges designed under the Standard Specifications must be built as HS25 (MS23) which is 125% of HS20, rehabilitations may be HS20 or lower. (To find metric tons multiply by 0.905).

The ***Inventory*** rating determines a live load that can safely utilize the bridge for an indefinite period of time, and is based on 55% of maximum allowable stress.

The ***Operating*** rating determines a live load that is the maximum permissible load that can safely utilize the bridge on an occasional basis, and is based on 75% of maximum allowable stress.

The ***Safe Load Capacity*** rating is between Inventory and Operating, and is used for bridge postings.

There are 3 types of bridge load ratings, to differentiate between varying comprehensiveness:

1). **Level I** – refers to any ***fully documented*** analysis or capacity evaluation that is ***signed and certified by a licensed professional engineer*** as being complete and correct in its computation of bridge load capacity.

Level I load ratings shall be based on AASHTO configuration for "HS", plus equivalent lane loads shall be used to determine rating values (if the HS Inventory rating is below HS20 (36 tons) the AASHTO configuration for "H" must also be computed).

Criteria for a level I:

a). Bridge is new, replacement, rehabilitated, or substantial structural alternations, UNIFORM CODE OF BRIDGE INSPECTION states that any bridge with substantial alterations, or built after 6/1/89, must have a certified set of plans, including a Level I rating table on the plan sheet.

b). Structural Integrity Evaluation to determine the safety and integrity of the bridge, the **SIE** shall include a Level I Load Rating or review of an existing Level I.

c). When the full legal load of the structure exceeds the Level II operating capacity.

2). **Level II** – Refers to a specific computerized load rating analysis, that is not certified by a P.E., based on bridge geometry and structural input, it calculates lead load and live load stresses to determine live load capacity rating for each structural element. The program does not rate for shear.

However, any ***uncertified rating*** analysis that substantially conforms to the provisions and assumptions of the **AASHTO MANUAL** may be referred to as a level II load rating. Level II ratings may be used to identify bridges that are likely to be load capacity deficient, in need of further evaluation, and may also be used to assign interim load posting pending completion of a Level I.

3). **Level III** – is a best estimate when no Level I load rating is available and the structure is not ratable by the Level II load rating program. Based on ratings of similar structures year of construction, and the general condition rating, the level III is not considered a very reliable source (but better than nothing).

FLAGS

In case of any deficiencies that have been located, there is a flagging procedure which sets forth a uniform method of timely notification of the appropriate responsible parties. **NYSDOT BRIDGE INSPECTION MANUAL (1997), "Appendix I" is Flagging Procedures** and establishes requirements for certifying that appropriate corrective or protective measures are taken within an appropriate time frame.

Flags are intended to : Handle conditions that are a clear and present danger.
: Handle conditions that if left unattended, will become a clear and present danger.

There are three flag types:

Red Structural Flag – To report the failure or potential imminent failure of a critical primary structural component.

Yellow Structural Flag – To report a potentially hazardous situation, that if left intact to the next anticipated inspection, could become a clear and present danger to a critical primary member. Also used to report actual or imminent danger to a non-critical structural member which would cause a reduction of reserve capacity or redundancy.

Safety Flag – To report a condition presenting clear and present danger to vehicle or pedestrian traffic, including under the bridge.

Prompt **I**nterim **A**ction (**PIA**) – When a safety or red flag condition is in critical need. (24 – hour response).

Flags have three planes of operations: Active, Inactive, and Removed.

QUALITY CONTROL

"The Q stands for <u>Quality</u> ..."

The **UNIFORM CODE OF BRIDGE INSPECTION** allows that after inspection, a **Q**uality **C**ontrol **E**ngineer (**QCE**), meeting the same qualifications as the general inspection team Leader (a P.E. with 3 years bridge experience), shall conscientiously provide an in-depth review and sign all field inspection reports, and flags. The QCE oversees and responds to the needs of the field bridge inspection teams, tracks their yearly progress, and compiles the information for submission to Quality Assurance in the main office.

DESIGN

Scoping as set forth in the **NYSDOT BRIDGE MANUAL** is *the process that establishes a genuine consensus about the nature and accomplishment of a proposed project.* All projects identified by NYSDOT are first addressed by the scoping process to achieve:

Project Objectives
Design Criteria
Feasible Alternatives
Reasonable Cost Estimates

To accomplish this many questions must be answered, such as:

- What will satisfy the projected future needs?
- What is the condition of the bridge?
    - Can it be widened, upgraded, rehabilitated?
    - Can any part of the existing structure be retained?
- Does the bridge have adequate opening?
- What is the community input? (Historical, Aesthetic, utilities, maintenance of traffic)
- Preliminary cost estimate?
- Work scheduling?

The answers to these questions should define the appropriate work and thus define the project objectives making the decision for: short term or long term repairs, or replacement.

Further information can be found in the **Project Development Manual**.

However defined, the project must assess any existing structure with regards to:

- Load carrying capacity.
- Material integrity.
- Acceptability of design details and practices.

As the preliminary engineering process becomes more project specific, more information is required, such as:

- What services must be maintained? (Fire and ambulances, school buses, utilities, etc.)
- How can traffic be maintained?
- Any special "site" construction considerations?
- How will the new bridge vary from the existing? (Wider or longer)
- Criteria to differentiate between rehabilitation and replacement procedures?
- Cost? and Schedule?

This results in more project specific findings and final recommendation can be made.
A **Final Design Report** presents the findings and **Design Approval** is sought.
A job specific **Site Data Package** is prepared.

The Region prepares and assembles the "Site Data Package" (for each structure in the project) to establish parameters for the final bridge design, verified for accuracy by the Regional Structures Engineer, it is provided to the bridge designer and consists of two parts: Part 1 must be completed for all structures, and Part 2 – waterway supplement must be completed for most structures over water.

A complete Site Data Package should be submitted to the bridge designer, one should be sent to the Geotechnical Engineering Bureau, and all Site Data necessary to perform a hydraulic analysis and evaluation must be submitted to the hydraulic engineer, as early as possible (typically 1 year). Appropriate portions may be submitted electronically.

The Regional Structures Engineer must review and approve, and upon completion of these reviews (and resolution of any major comments), the objectives of the project have been finalized, and work can begin on the final design and preparation of the **Plans, Specifications and Estimate (PS&E)** package.

THE PRELIMINARY PLAN PROCESS: New or Replacement structures.

The preparation of a Preliminary Structure Plan is the first step in preparing final bridge plans for inclusion in a **PS&E** package. The Preliminary Structure Plan presents in a clear and precise manner what the designer intends to do to solve the bridge problem defined in the project scope. The proposed solution should be compatible with the overall conditions of the site (geometric, topographical, cultural, ecological, etc.), and should be consistent with the cost, scope, and schedule set for the project.

1). Collect Support Data

a). Design Approval Document (**DAD**) – Provides the latest project definition.

b). **C**ost, **S**chedule, **S**cope and **Q**uality **A**greement (**CSSQA**) – Provides management relationships, project plan, schedule and cost estimate.

c). Bridge Site Data Package – This package provides the designer with the information required to select a structure for a specific site. It also provides the hydraulic engineer with the data needed to perform a hydraulic analysis and it defines any outside agency requirements (utilities, DEC, etc.)

2). Develop the Structure Study Package

Referred to as "advance preliminary" or "40% preliminary" or "size, type and location", to assure that all issues and questions regarding the concept of the proposed structure are addressed as early in the design process as possible.

Size, type, location and orientation of the structure are the major items investigated at this time. For a typical structure, a Structure Study Plan should include the following information:

Location map*
Plan view (1:200) showing bridge centerline and features crossed
Substructure locations (existing and proposed)
Span lengths
Elevation view (1:200) or larger (1:100)
Minimum clearances (horizontal and vertical)
Full Transverse Sections of proposed bridge & approach highway including proposed staging details (if applicable) and utility locations (if applicable)
Existing and proposed boring locations
Profile of all roads and/or railroads, including banking diagrams*
Typical highway section (under)* including side slope treatment to and through the structure
Horizontal alignment data
(*included in Design Approval Document (if available)

3). Prepare **Structure Justification Report (SJR),** which documents the selection of this particular design; structure size, type and location (as noted in the Structure Study Plans). Topics detailed should include a discussion of design, such as (not limited to) the following:

Superstructure type, configuration, materials
Substructure type, foundation constraints (if known)

Discussion should also include factors affecting the selection of this design (may include, but not exclusive to the following):

Constraints (such as hydraulic, M&PT, Railroad, ROW, utilities, etc.),
Design exceptions due to substandard features (e.g., sag curve and crest curve).
Brief narrative of existing hydraulic conditions at the site (e.g., ice, debris)
Subsurface conditions; soil, foundation type, temporary sheet pile/lagging system
Any special features (e.g., aesthetic treatments)
Anticipated construction problems, Construction cost estimates
Alternative structures eliminated from the selection and reasons for denial

4). Prepare a **Preliminary Cost Estimate**

The NYSDOT standard for the estimate is a shoulder break square foot unit cost basis, developed by the Structures Division for use in projects where bridge particulars, such as abutment heights and locations are not known. The current estimating procedure (should break method) provides reasonable compensation for positioning abutments anywhere within the shoulder break length along the shoulder break slope line. The user is also provided with project level information.

5). Establish **Hydraulic Criteria** for bridge projects over water.

The designated hydraulics engineer, the Structures Division Hydraulic Unit, the Regional Hydraulics Engineer, or a design consultant will provide the designer with a hydraulic summary which includes a preliminary "Hydraulic Data Table". The summary will document the review of the proposed structure regarding freeboard and scour requirements, and document other hydraulic requirements considered in the selection of the type and size of the structure. Hydraulic criteria for any temporary structure will also be required.

Prepare **Hydraulic Justification Report**, Hydraulic Engineer will provide the designer with a Hydraulic Justification Report, (HJR) to be appended to the SJR, prior to submitting the completed Preliminary Plan Package to the Deputy Chief Engineer (Structures) for approval.

The design criteria for new structures is a 50 year flood (with an allowance for 2' of freeboard). The analysis procedures to be followed are outlined in the **NYSDOT Hydraulic Manual**, and the appropriate sections of the most recent **Standard Specifications for Highway Bridges**.

6). **Perform In-Progress Technical Review**

A progress review of the structure study package (structure study plan-structure justification report-preliminary cost estimate-hydraulic criteria) is performed at this time to ensure that the structural solution being developed is consistent with the scope of the project, is technically and economically appropriate, and responds to the site conditions, restrictions, etc., that have been identified.

7). Transmit for Final Review

The completed Preliminary Structure Package (revised Preliminary Structure Plan, revised SJR, revised Preliminary Cost Estimate, and the HJR shall be submitted for final review.

8). Resolutions of Final Review Comments and Approvals

The final comments are resolved and a revised Preliminary Structure Package is sent to the Deputy Chief Engineer (Structures) for approval.

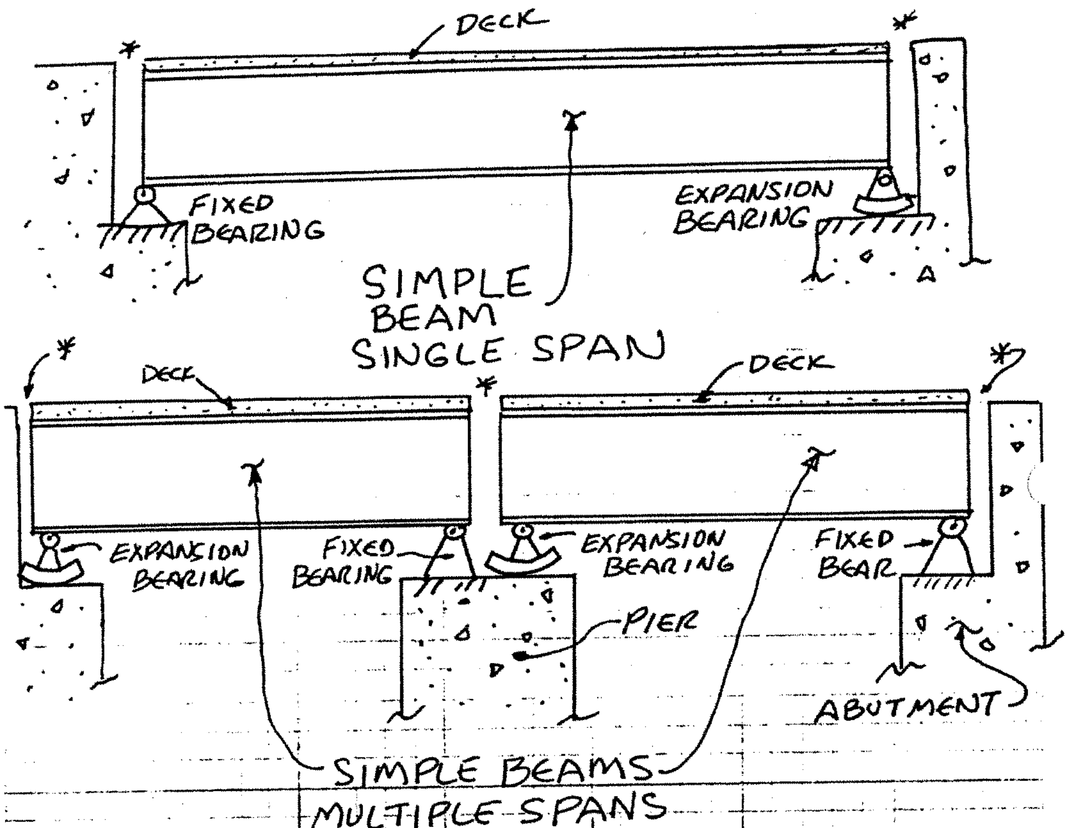
9). Distribution of Approved Preliminary Bridge Plan

N.Y.S. DEPARTMENT OF TRANSPORTATION

Sheet ____ of ____ Prep. by ____ Date ________
Checked by ____ Date ____ Design Ident.: SH.No. ______
County ______________ P.I.N. ________
Job Title ______________________

CONSTRUCTION JOB STAMP

BRIDGE TYPES: 1 of 2



* LOCATIONS WHERE BRIDGE DECK JOINTS WOULD BE PLACED.

NOTICE: Each Simple Span has 1 Expansion and 1 Fixed Bearing.

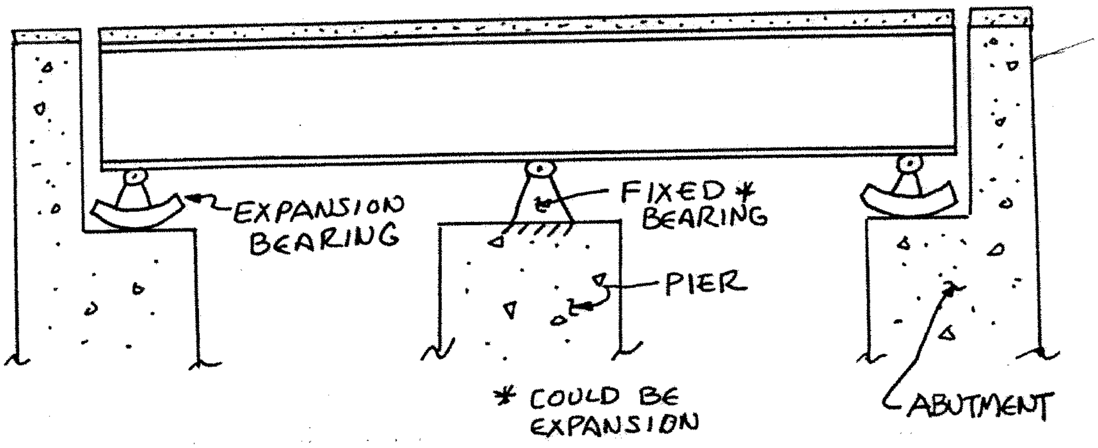
DIST 22a (12/73) I.R. No. __________ Prep. by ________ Date ________ Checked by ________ Date ________

N.Y.S. DEPARTMENT OF TRANSPORTATION

Sheet ___ of ___ Prep. by ___ Date ___
Checked by ___ Date ___ Design Ident.: SH.No. ___
County ___ P.I.N. ___
Job Title ___

CONSTRUCTION JOB STAMP

BRIDGE TYPES: 2 of 2



CONTINUOUS BEAM
MULTIPLE SPAN.

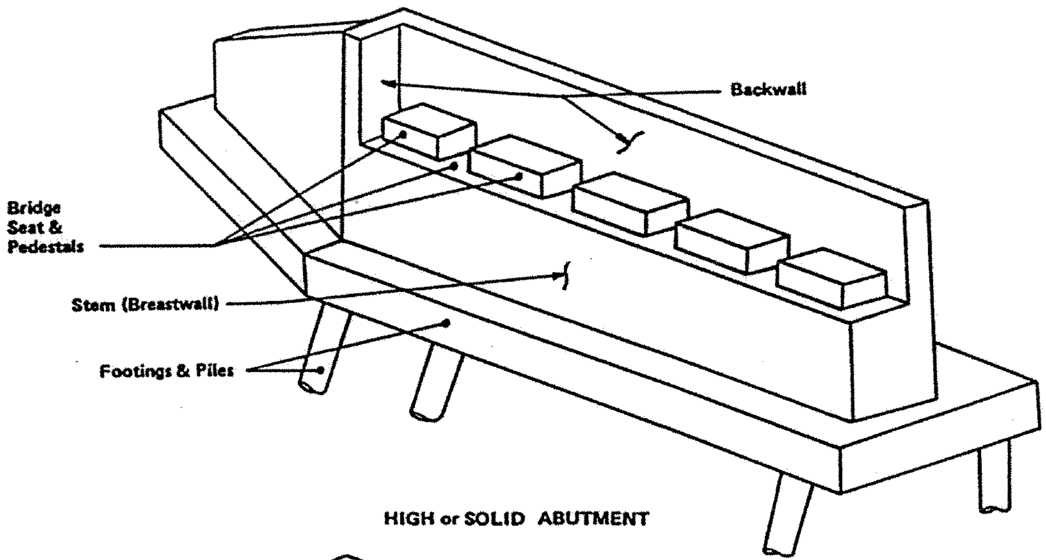
NOTE: BEAM IS CONTINUOUS OVER PIER.

ADVANTAGES OF CONTINUOUS BEAM OVER SIMPLE SPAN BEAMS:

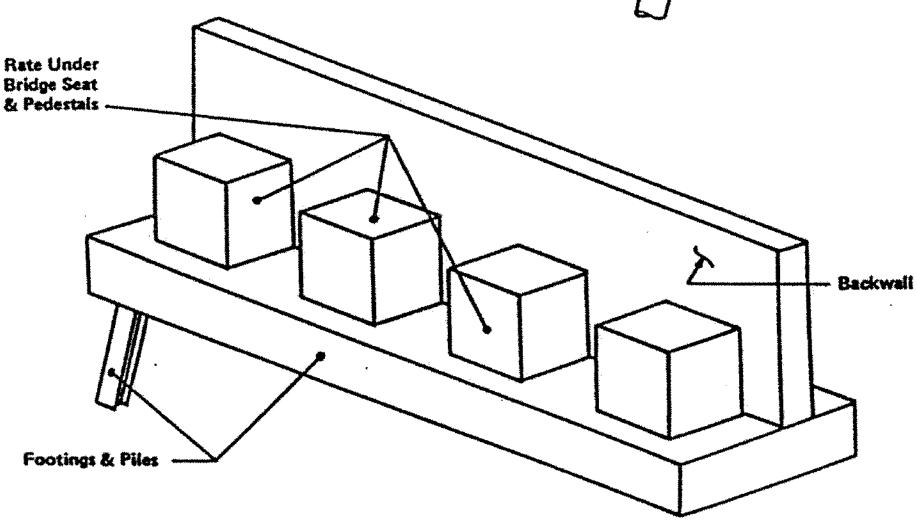
1. Less Steel Generally Required $
2. No Bridge Deck Joint Needed over Pier, which would eventually leak and cause damage to pier.

DIST 22a (12/73) I.R. No. ___ Prep. by ___ Date ___ Checked by ___ Date ___

TYPICAL ABUTMENT TYPES

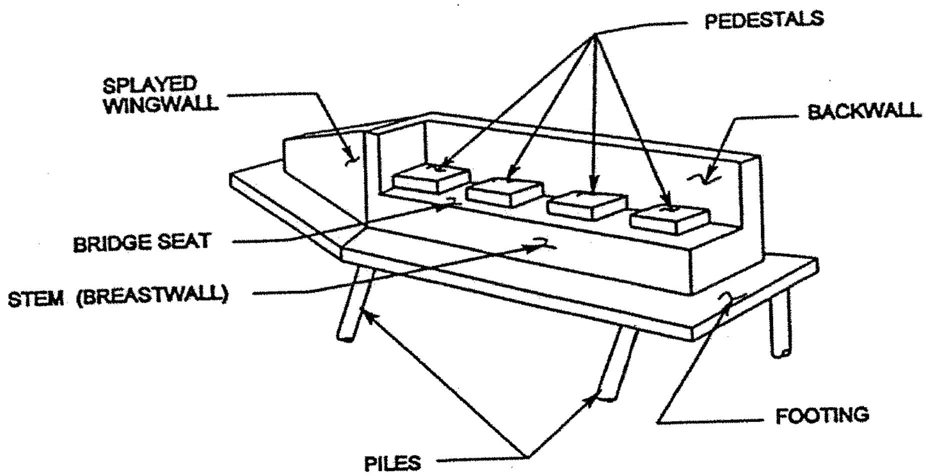


HIGH or SOLID ABUTMENT

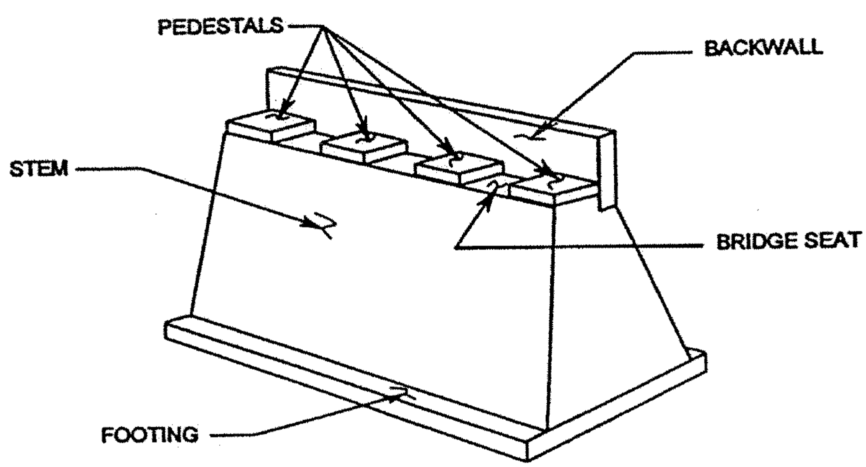


STUB ABUTMENT
(Wingwalls Not Shown)

TYPICAL ABUTMENTS

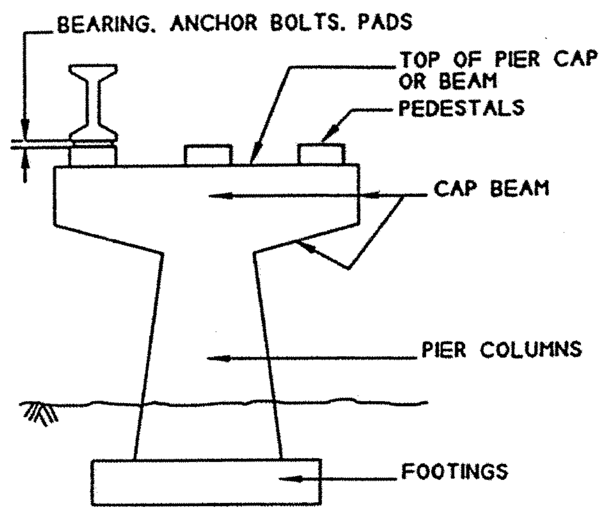


TYPICAL FULL HEIGHT ABUTMENT

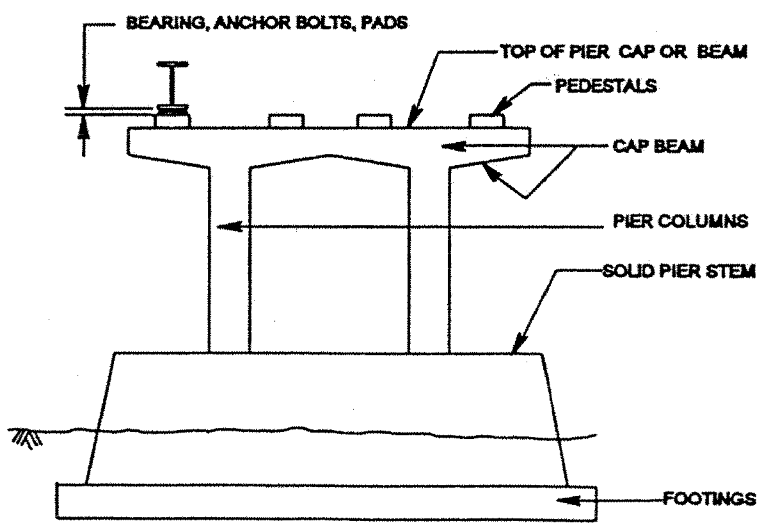


TYPICAL GRAVITY ABUTMENT
(Wingwalls not Shown)

(NO PILES)

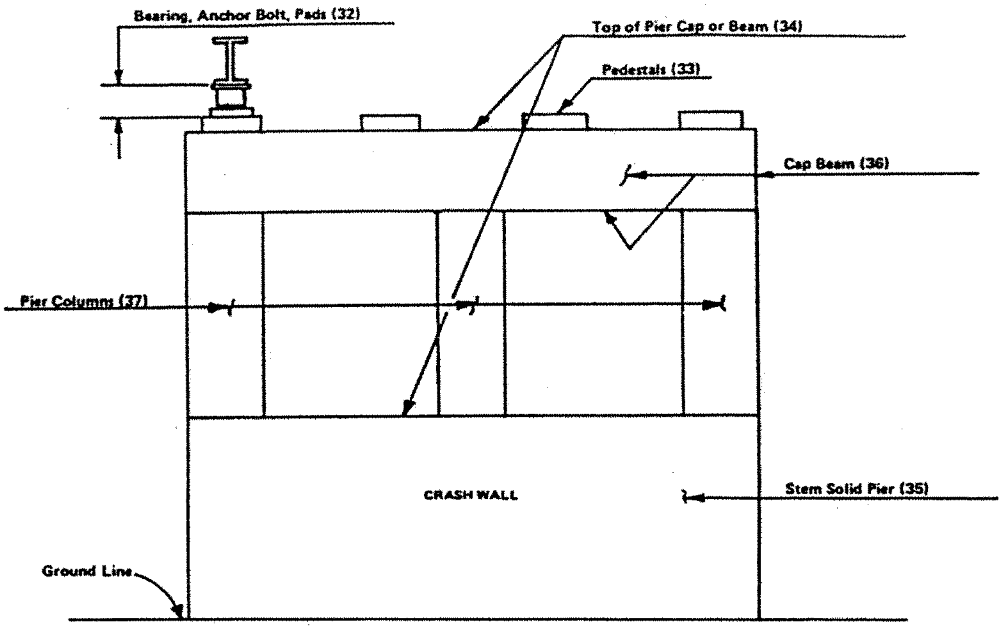


TYPICAL HAMMERHEAD PIER

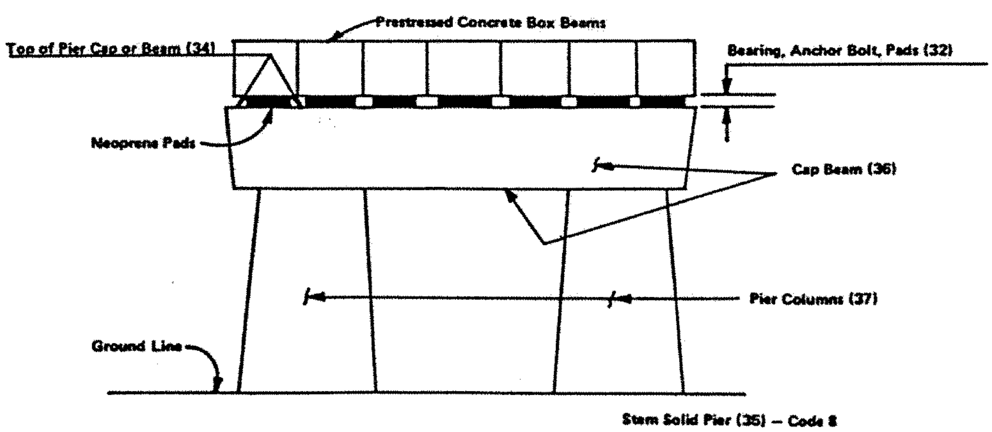


TYPICAL DOUBLE HAMMERHEAD PIER

PIER TYPES

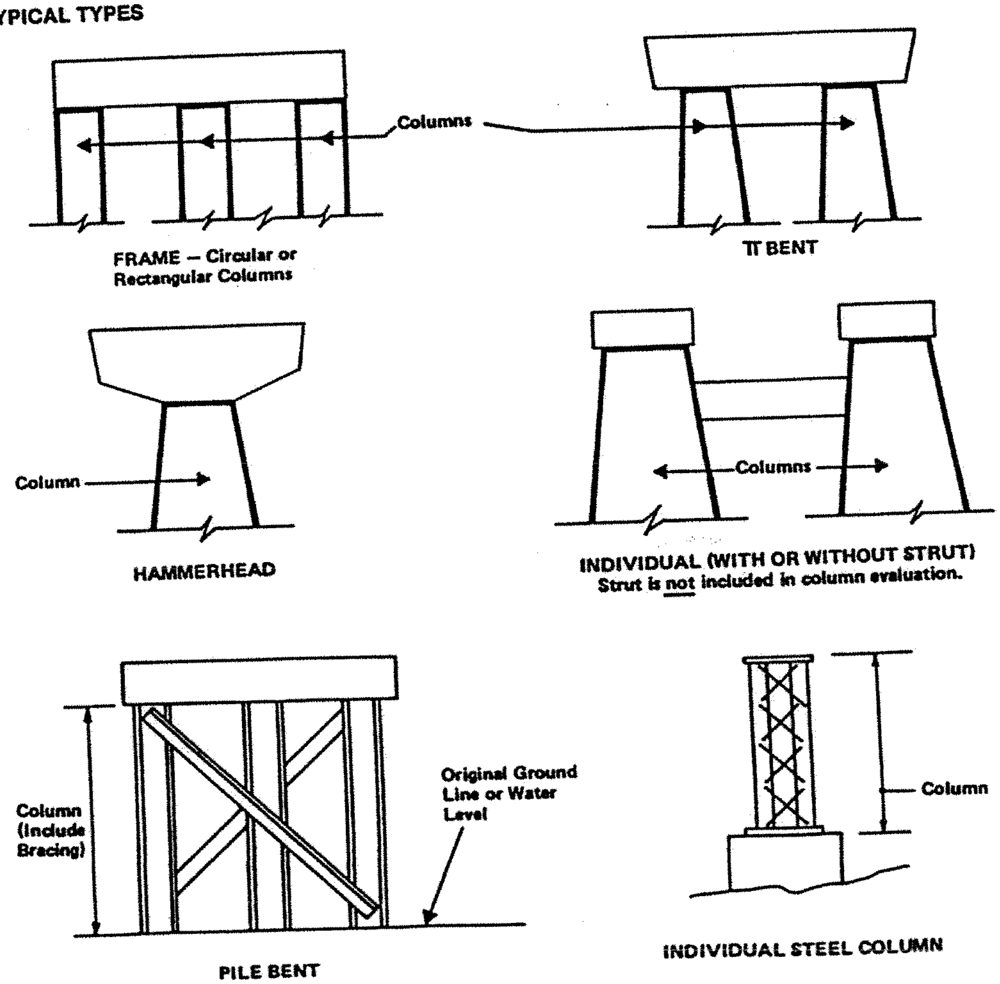


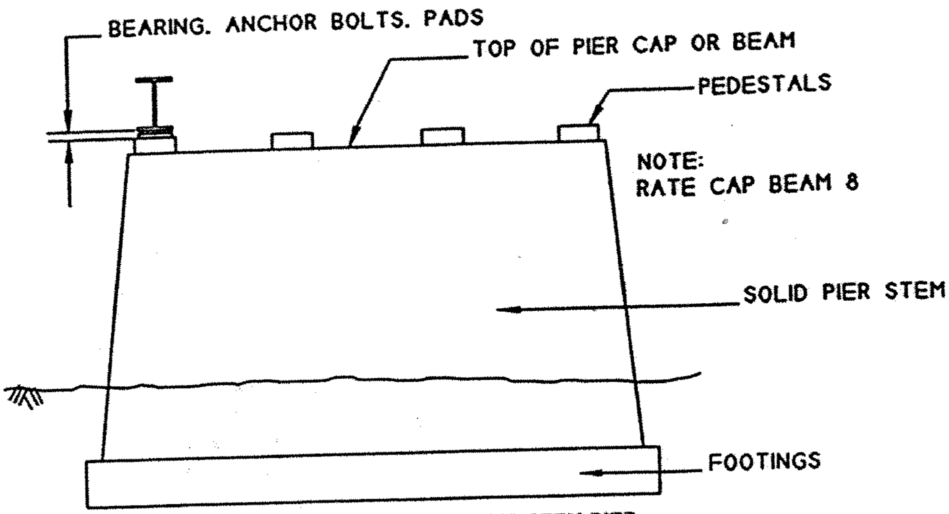
FRAME PIER



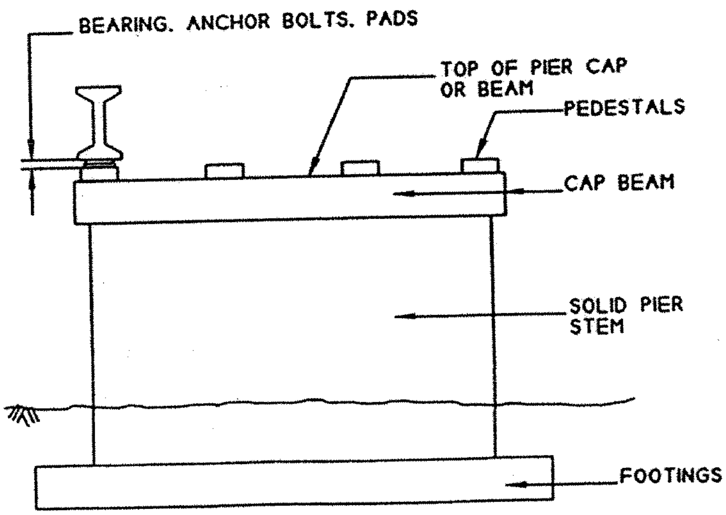
PI (Π) PIER

TYPICAL TYPES

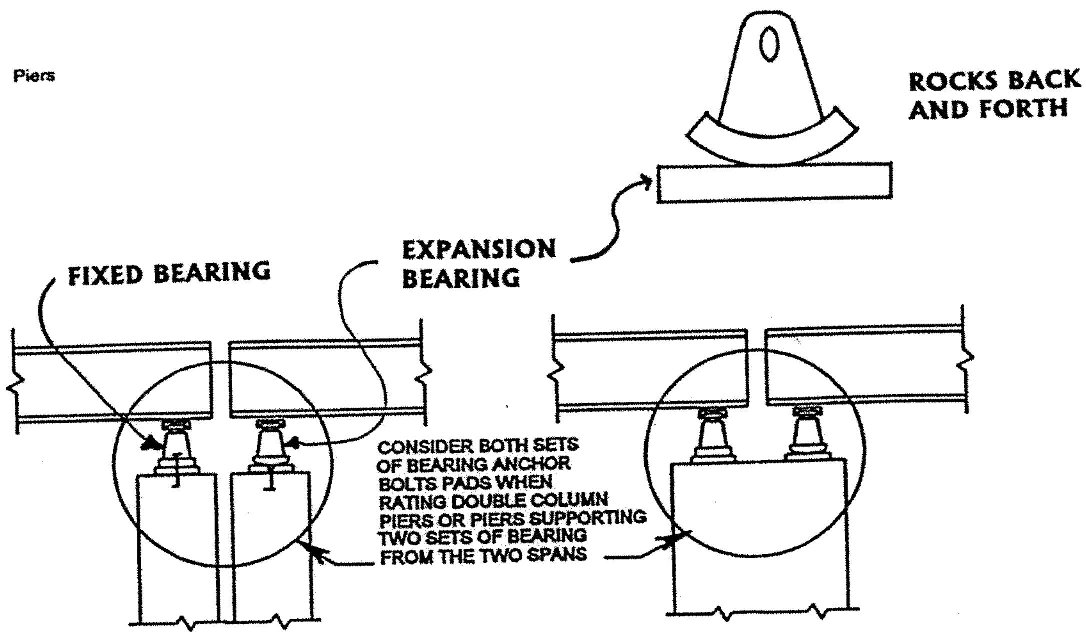




TYPICAL SOLID STEM PIER
(No Cap)
Figure 4D.1.12



TYPICAL SOLID STEM PIER WITH CAP

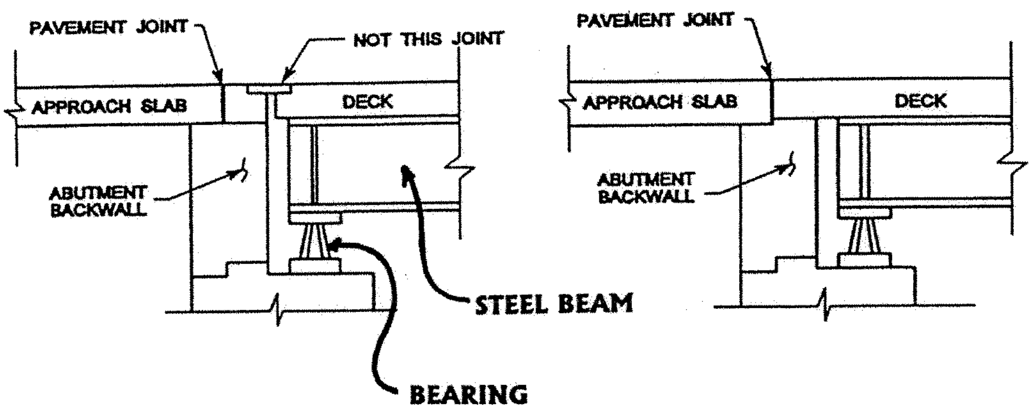


SIMPLE BEAMS & SUPPORTS

TWO SETS OF BEARINGS AT A PIER

Figure 4D.2.1

PAVEMENT
(Approaches)

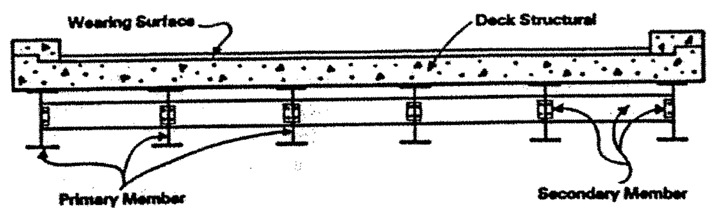


APPROACH PAVEMENT JOINT

BRIDGE TYPES

STRINGER BRIDGE

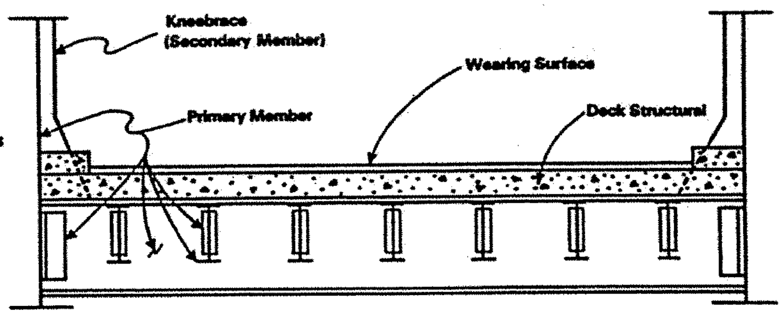
Primary Member	Secondary Member
Stringer	Diaphragm



STRINGER SPAN

GIRDER BRIDGE

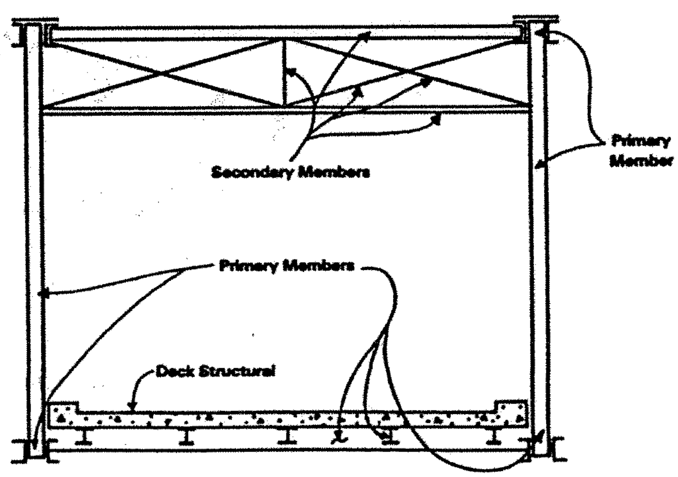
Primary Member	Secondary Member
Stringers Floorbeams Girders Str./Flbm. Conn. Flbm./Gir. Conn.	Knee Braces



GIRDER SPAN

TRUSS BRIDGE

Primary Member	Secondary Member
Truss Truss Connection Floorbeams Truss/Flbm. Conn. Stringer Str./Flbm. Conn.	Portals Lacing Bars Battern Plates Stay Plates Diagonal Bracing



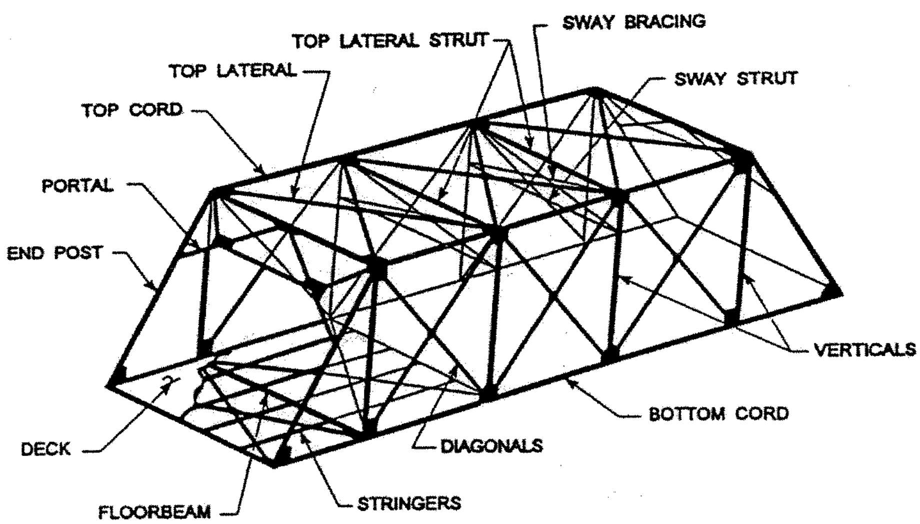
TRUSS SPAN

METAL TRUSSES

The most common truss type used for bridge construction is two-dimensional with members designed to withstand axial forces. The primary member rating is based on the ability of the superstructure to carry the loads for which it was designed. Truss members, floorbeams, and their connections are generally non-redundant, and integrity of the entire superstructure system is dependent upon condition of each individual element. A single member or connection in poor condition can dramatically influence primary member rating for the affected span.

Typical Trusses

- Simple truss
- Continuous truss
- Pin-connected truss
- Pony truss
- Through truss
- Deck truss

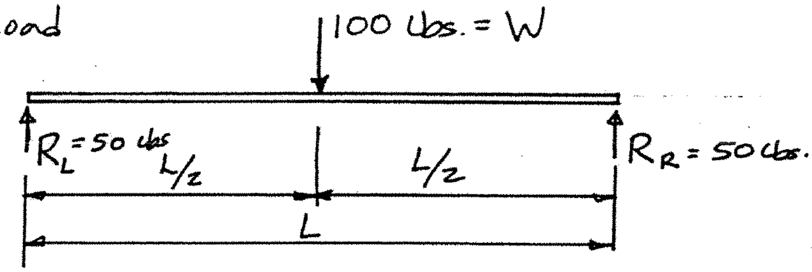


TRUSS MEMBERS AND ELEMENTS

Simple BEAM Problems

R = reaction such as load that is applied vertically to bearings on a bridge.

W = Load



Since the 100 Lbs is "exactly" in the middle of the beam, R_L = 50 Lbs and R_R = 50 Lbs

OR. $R_L = R_R$ and $R_L + R_R = W$

↑R_L, ↑R_R and ↓W Represent Forces

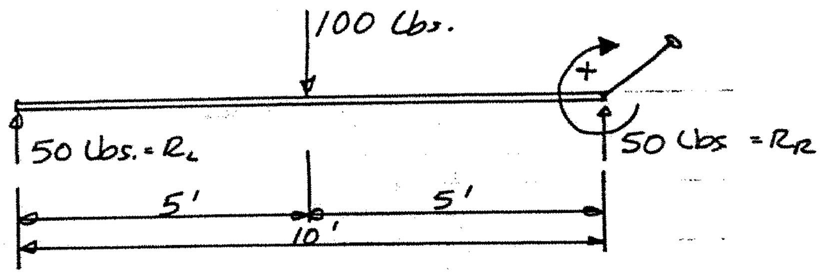
The summation of All Forces in the Vertical Direction Must Equal Zero

Say Up is positive "+" and Down is negative "−"

+ 50 Lbs + 50 Lbs − 100 Lbs = 0 ✓

THIS HOLDS TRUE FOR ALL BEAMS & LOAD CONFIGURATIONS

SAME BEAM: Say L = 10 Ft.



Say we hammered a nail at R_R, and rotated the beam in a clockwise manner with R_L. The leverage would be 50 Lbs x 10 Ft. or 500 Ft. Lbs. However, the beam really is not moving. This rotation is resisted by the 100 Lb load x 5 ft. in a counter-clockwise direction.

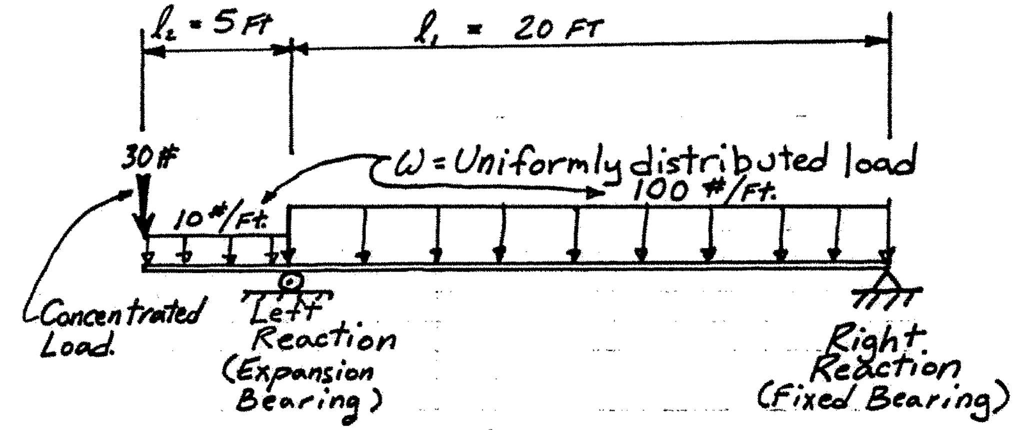
Again, since this beam is not rotating, the summation of all loads x distance from the pin must equal zero.

Calling Clockwise rotations positive (+)

$+(50_{RL} \text{ Lbs} \times 10') - (100 \text{ Lbs} \times 5') = 500 - 500 = 0$ ✓

If we hammered a nail at R_L, after removing the nail at R_R, we could repeat the process.

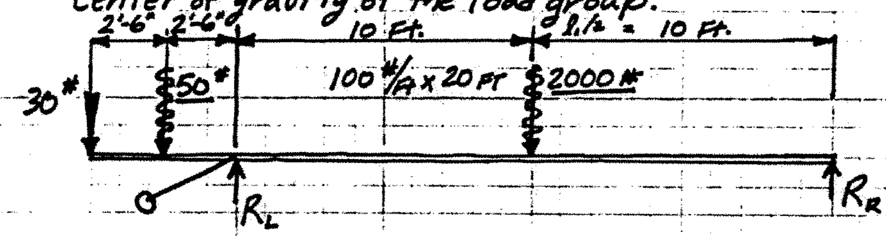
"FINDING REACTIONS AND MOMENTS"



Represents a uniformly distributed load such as Asphalt, Concrete Bridge Deck, Snow, Soil ect.

A "UDL" may always be represented by the resultant load for the purposes of calculating reactions.

The resultant load equals the load per ft. times the length of the load, and is applied at the center of gravity of the load group.



To Find R_R assume a nail is located at R_L.
Assume rotations in clockwise direction are positive. (+)

$$(2000\# \times 10) - (50\# \times 2.5) - (30\# \times 5.0) - (R_R \times 20) = 0$$

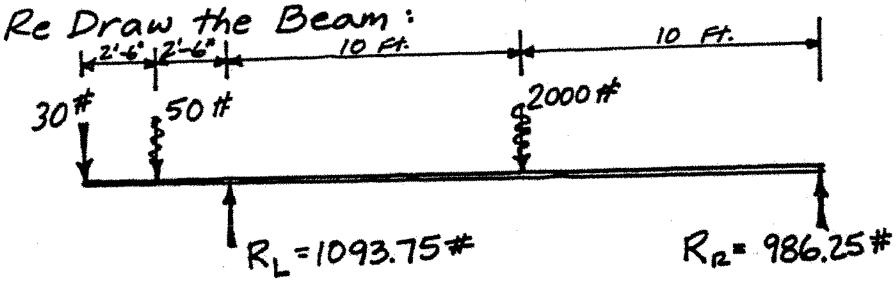
This equation equals zero because beam is not really rotating "static equilibrium".

$-125 - 150 + 20000 - (R_R \times 20) = 0$

$19725 = R_R \times 20$

$R_R = 986.25\#$

Re Draw the Beam:



Since the beam is <u>not</u> <u>accelerating</u> up or down, the sum of all the forces or loads in the vertical direction, (Up or Down), <u>MUST</u> <u>EQUAL</u> <u>ZERO</u>. Assume Up ↑ is positive.

$+R_L - 30\# - 50\# - 2000\# + 986.25\# = 0$

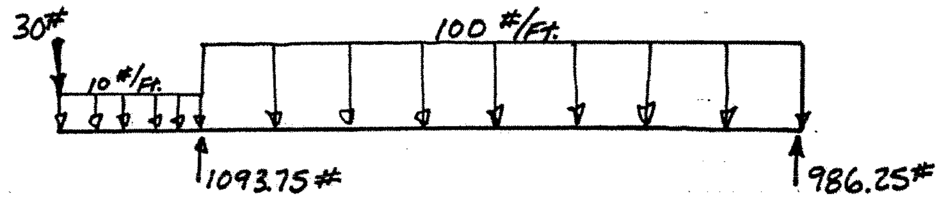
$R_L = 1093.75\#$

* As a check, put a nail in R_R and check rotations to see if they equal zero.

Ans: (+) $-(30\# \times 25\text{ Ft.}) - (50\# \times 22.5\text{ Ft.}) + (1093.75\# \times 20)$

$-(2000\# \times 10\text{ Ft.}) = 0$ check ✓

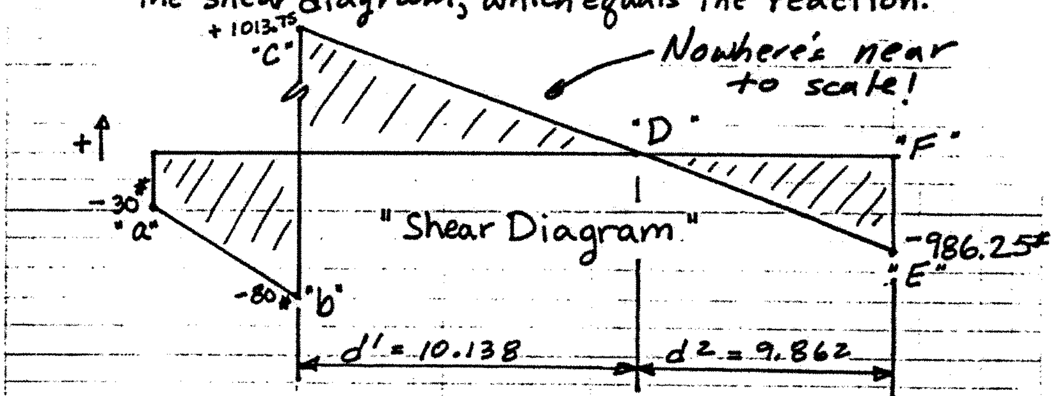
Re Draw Beam Again!
(Do Not Draw Resultants)



Shear: At any point on a beam is equal to the sum of the vertical forces.

Moment: A measure of the bending or curvature of a beam due to applications of loads

On a beam with simple supports, the shear at the support equals the reaction, or in other words, as at R_L the shear equals the vertical jump in the shear diagram, which equals the reaction.



Note: This is the Shear Diagram, units in Pounds#. Calculations follow for the points.

To do this the easiest and right way, the shear diagram should be on top of the page, with the moment diagram & deflection curve directly below it.

N.Y.S. DEPARTMENT OF TRANSPORTATION

Sheet 4 of 5 Prep. by NJD Date ______
Checked by ______ Date ______ Design Ident.: SH.No. ______
County ______ P.I.N. ______

CONSTRUCTION JOB STAMP

Job Title ______

To calculate the values of the points, just follow the arrows up and down. For instance: ↑+

Point "a" Down 30# a = −30#

Point "b" −30# − (10#/Ft × 5 Ft.) = −80#
b = −80#

Again @ Point b from −80# go up 1093.75 #
to get to Point C
−80 # + 1093.75 # = 1013.75 #
C = + 1013.75 #

Skip D for now, go to E

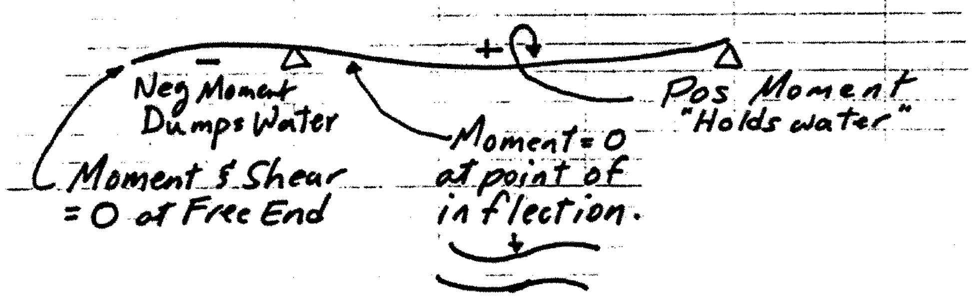
Starting from point "C" "+1013.75 − (100 #/Ft × 20 Ft)
= −986.25 #
E = −986.25 #

NOTICE: The value of point E is equal to the Right Reaction but opposite sign. ! When added, they will equal zero!

This brings us to "F" which is a check that everything was done correctly. ✓

F = 0 ✓

The location of Point D is <u>very important</u>. At points where the shear diagram = 0, the Moment Diagram Maxes Out in either a pos or neg way.



DIST 22a (12/73) I.R. No. ______ Prep. by ______ Date ______ Checked by ______ Date ______

N.Y.S. DEPARTMENT OF TRANSPORTATION

Sheet 5 of 5 Prep. by NJD Date ______

Checked by ______ Date ______ Design Ident.: SH.No. ______

County ______ P.I.N. ______

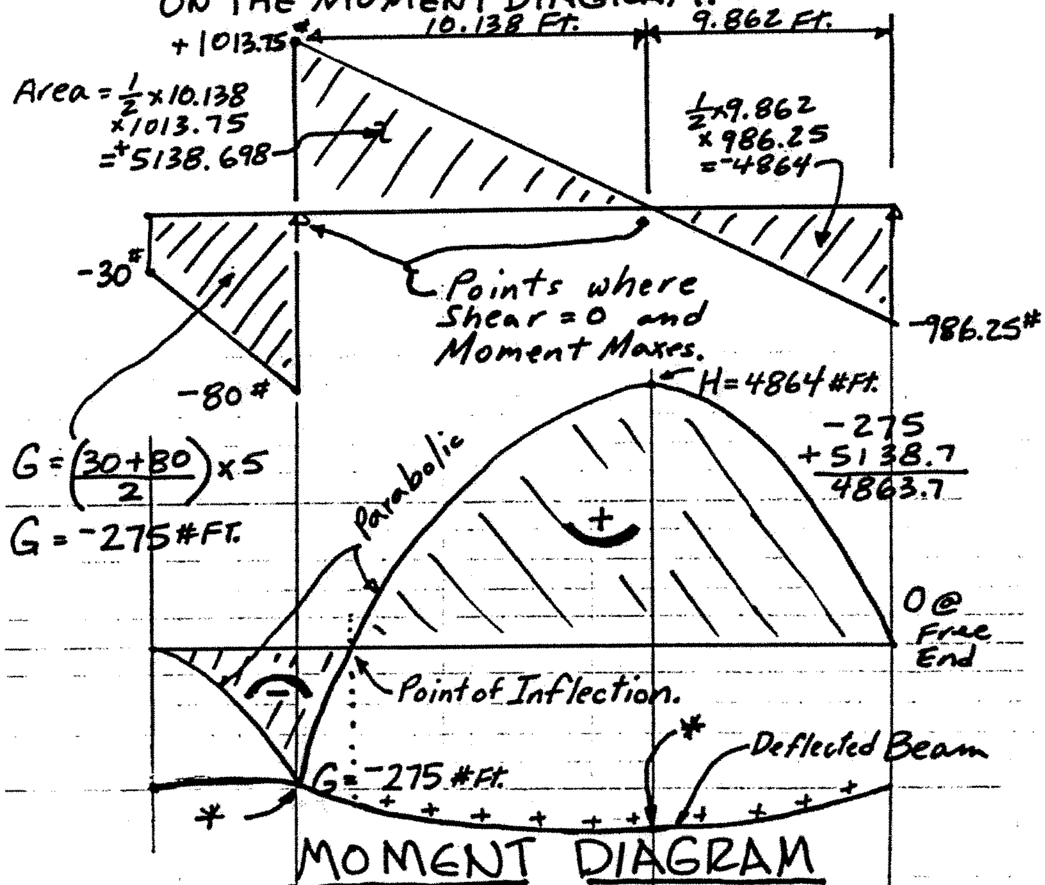
CONSTRUCTION JOB STAMP

Job Title ______

To find dimension d' Shear = 0

$$1013.75 - 100\#/Ft. \times d = 0$$
$$1013.75 = 100\#/Ft \times d$$
$$10.138\ Ft = d'$$
$$d^2 = 20 - 10.138 = 9.862\ Ft.$$

NOW: RE DRAW SHEAR DIAGRAM & USE IT TO DRAW MOMENT DIAGRAM! THE AREAS OF THE SHEAR DIAGRAM EQUAL THE ON THE MOMENT DIAGRAM.



*If They were drawn well, areas of max curvature.

DIST 22a (12/73) I.R. No. ______ Prep. by ______ Checked by ______ Date ______

STRUCTURAL DESIGN METHODOLGIES

There are three different design methodologies for the structural design of bridges. Service Load Design and Load Factor design are governed by the NYSDOT Standard Specifications for Highway Bridges. Load and Resistance Factor Design (LRFD is governed by the NYSDOT LRFD Bridge Design Specifications.)

Service Load Design, also known as Allowable Stress Design (ASD) is the oldest and generally most conservative design method. ASD achieves its factor of safety by limiting the stresses on the member to some percentage of the maximum stresses that the member could take before yielding. Since the dead load and live load stresses are considered at the same time, there is no provision accounting for the greater certainty of dead loads. Thus, there is no consistent factor of safety on live load. As span length increase and dead loads become a much higher percentage of the total load. ASD can become overly conservative and less economical.

Load Factor Design achieves its factor of safety by applying – multipliers or load factors to the design loads. These multipliers increase the load effects or stresses applied to the member above those induced from the design loads alone. Since the dead loads are known with a greater degree of certainty, the load factor applied to them is relatively small. By comparison, live loads are highly variable and, therefore, the applied load factor is relatively large. The factored stresses are then compared to the yield stress, or ultimate capacity of the loaded member.

Load and Resistance Factor Design (LRFD) is now the preferred methodology for bridge design. Resistance factors are applied to member capacities to account for reliability of various material types. Load factors are applied to design loads as in Load Factor Design. LRFD introduce various limit state as a design philosophy and uses structural reliability methods to achieve a more uniform level of safety. The LRFD code defines four design limit state categories:

- Strength Limit States
- Service Limit States
- Fatigue Limit States
- Extreme Event Limit States

REFERENCES

1. NYSDOT Bridge Manual
2. NYSDOT Standard Specifications for Highway Bridges
3. NYSDOT LRFD Bridge Design Specifications
4. NYSDOT Bridge Inspection Manual
5. NYSDOT Bridge Inventory Manual
6. NYSDOT Bridge Safety Assurance Vulnerability Manuals