STUDY REPORT

JAPAN INTERNATIONAL COOPERATION AGENCY

Volume 2/4
(APPENDIX)

THE KINGDOM OF THAILAND

STUDY REPORT

ON

THE PROJECT OF STRENGTHENING AND/OR REPLACEMENT
OF STEEL BRIDGES ON THE STATE RAILWAY OF THAILAND

A Sub-Project for The Trans-Asian Railway Project
of The Economic and Social Commission
for Asia and The Pacific(ESCAP)

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APPENDIX I

SPECIFICATIONS FOR DESIGN

CHAPTER I. GENERAL

1-1 Scope of Application

These design specifications shall be applied to the design for repair, strengthening and replacement of existing steel railway bridges with spans not longer than 90 meters.

Specifications for Design of JNR; Railway Bridge
Specifications for Design 1971, JNR

1-2 Construction Gauges

Construction gauges, clearance under bridge and other limits for bridge construction shall be specified by respective relevant regulations. (refer to construction gauge, RSR Drawing No. 1966-15), provided that these construction gauges shall not be applied to existing members or elements of bridges.

CHAPTER II. LOADS

2-1 Types of Loads

In the design of bridges the loads listed in Table 2-1 shall be taken into consideration.

Table 2 - 1

Types of Loads		Symbols	
Principal Loads	Dead Load	P	D
	Train Load		L
	Impact		I
	Centrifugal Force		C
Secondary Loads	Lateral Force due to Train	L_F	
	Braking Force and Traction Force	B	
	Wind Load	W	
Other Loads	Effect of Temperature Change	T	
	Force due to Earthquake	E	
	Load in Erection	E_R	
	Longitudinal Force due to Long Rails	L_R	
	Load on Sidewalk	F	

2-2 Dead Load

2-2-1 In the calculation of dead load, the unit weight given in Table 2-2 shall be used as a rule

TAble 2 - 2

Materials	Unit Weight (kg/m^3)
Steel, Cast Steel	7,850
Wrought Iron	7,800
Cast Iron	7,250
Timber	1,100
Ballast Gravel or Crushed Stone	1,900
Concrete	2,350
Reinforced Concrete	2,500
Mortar	2,150
Water-proof Asphalt	1,100
Copper Alloy Bearing Plate	8,500

2-2-2 a) Steel Rail .... 40 kg/m
R.S.R. Standard Section (Drg. No. 1882-116).

b) The dimensions of a sleeper are 220 x 20 x 18cm. Sleepers are placed at a spacing of 50cm center to center.

c) The minimum weight per unit length of an ordinary non-ballast type track shall be assumed as 450kg/m as a rule.

2-3 Train Load

2-3-1 Train Load

The axle arrangement and weight of the train load shall be as shown in Fig. 2-1. The train load shall be DL-14 Loading for checking the load capacity of bridges. Bridges which are overstressed by DL-14 Loading shall be strengthened according to DL-15 Loading.

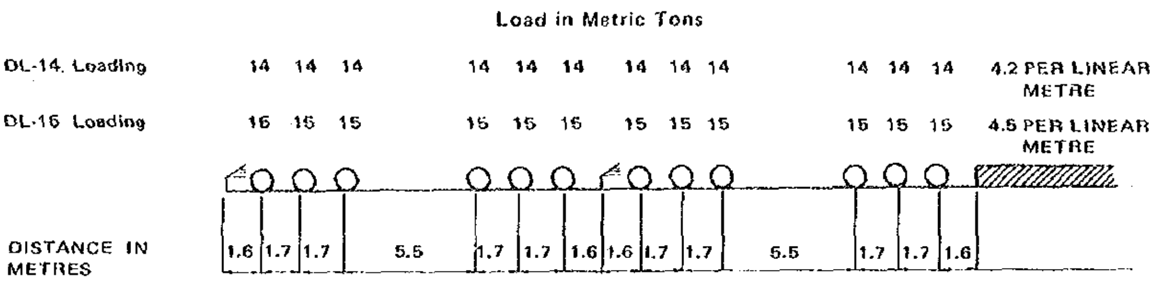


Fig. 2-1

2-3-2 Loading Method of Train Load

(1) The locomotive load shall be taken on the basis either of single engine or double engine traction, and trailing uniform load shall be taken for any desired length, in such a manner as to cause a possible maximum stress on structural members under consideration.
As a rule, the load shall not be separated to be put on more than two sections apart.

(2) In the case of a double-track bridge, the trains on the two tracks shall be placed in the same or opposite directions, so that the structural members under consideration may be subjected to the largest stress.

2-3-3 Train Load in Case Fatigue Effect is Examined in Calculation

When fatigue effect is examined, calculation shall be as a rule carried out for single-track loading even in the case of a double-track bridge.

2-4 Impact

(1) The impact shall be assumed to be caused by the train load as specified in Para. 2-3-1 and the stress due to the impact shall be the product of the train load stress multiplied by the impact coefficient "i" given below.

$$L \leqq 30m \qquad i = 0.7 - \frac{L^2}{4000}$$

$$L > 30m \qquad i = \frac{10}{L} + 0.14$$

Where L shall be as a rule the length (m) of the base line of influence line of the same sign that cuases a possible maximum train load stress in the structural members under consideration. However, with regard to the web members of a truss except the hip vertical members of a through truss, intermediate posts of a deck truss and diagonal members in sub panels, L shall be taken as 75% of the bridges span length. (Same in Para. 2)

(2) The impact coefficient for the members supporting a double track shall be the product of the impact coefficient specified in the preceding paragraph multiplied by the factor "α" given below.

$L \leqq 80m \qquad \alpha = 1 - \frac{L}{200}$

$L > 80m \qquad \alpha = 0.6$

2-5 Centrifugal Force

With respect to a bridge having a curved track, a centrifugal force equal to the train load prescribed in Para. 2.3.1 multiplied by the coefficient shown in Table 2-3 shall be considered. As a rule, the centrifugal force shall be assumed to act horizontally at a height 1-8 meters above the rail level and at a right angle to the bridge axis.

Table 2 - 3

Radius of Curvature R(m)	Coefficient
$R \leqq 1000$	0.12
$1000 < R < 2000$	0.08
$2000 \leqq R$	0

2-6 Lateral Force due to Train

The lateral force due to train motion shall be assumed as a moving load shown in Fig. 2-2. It shall act, as a rule, horizontally on the rail level at a right angle to the bridge axis. Its magnitude "Q" shall be 15% of the driving wheel axle load of the train load specified in Para. 2-3-1.

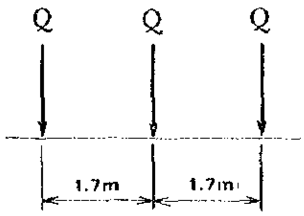


Fig. 2-2

2-7 Braking Force and Traction Force

The braking force and traction force shall be equal to the values given below. As a rule, these loads shall be assumed to act in the direction of the bridge axis at a height of 1.8m above the rail level.

(1) Braking force: 15% of the train load.
(2) Traction force: 25% of the weight of the driving axles.

2-8 Wind Load

1) The wind load shall in principle be assumed to act horizontally and at a right angle to the bridge axle and its magnitude shall be as specified below.

* For the projected area of the bridge on the vertical plane; $150kg/m^2$
* For the projected area on the vertical plane of the leeward truss members not shielded by the floor system; $100kg/m^2$
* For the projected area on the vertical plane of the train; $150kg/m^2$

The projected area on the vertical plane of the train shall be assumed as an equivalent to a vertical plane with a height of 3.5 meters standing on the rail top, and with regard to the windward and leeward bridge members overlapped by the train, the wind load shall not be taken into consideration.

2) As for the through truss bridge with a span of up to 80 meters, the values shown in Table 2-4 shall be usually taken as the total of windward and leeward wind loads despite the stipulation in the preceding paragraph.

Table 2 - 4

(in kg/m)

Upper Chord	Lower Chord
150	400*

Note: *Wind load to the projected area on the vertical plane of the train is included.

2-9 Force due to Earthquake

The horizontal seismic intensity to be taken into consideration for design shall be 0.1 as a rule, and in the checking with regard to overturn, a vertical seismic intensity of 0.05 shall be considered to act upward.

2-10 Temperature Change

1) In Regard of statically indeterminate structure, a minimum of 15°C and a maximum of 50°C shall usually be taken into account for the entire structure.

2) The coefficient of linear expansion of steel shall be 0.000012 per centigrade degree.

2-11 Longitudinal Force due to Long Rails

The longitudinal force due to long rails shall be 0.5t/m per track and assumed to act at the rail base in parallel with the bridge axis.

2-12 Loads on Bridge Sidewalk

1) The live load on bridge sidewalks shall be assumed in principle to be 300kg/m in a width of one meter and no impact shall be taken into consideration.

CHAPTER III. MATERIALS

3-1 Materials in General

The materials to be used for new steel bridges and for repair and strengthening of existing bridges shall be those specified by Specifications for Design of JNR or of equivalent or heigher quality. The materials of existing bridges or dismantled bridges shall be examined by material test.

CHAPTER IV. ALLOWABLE STRESS

4.1 Allowable Stresses

1. The stress in the bridge members due to the principal loads and the stress due to one of the secondary loads shall not exceed the allowable stresses specified in Para. 4-2 to 4-3.

2. With respect to influence of fatigue, only the stresses due to dead load, train loads (in the loading conditions as specified by 2-3), impact and centrifugal force shall be checked.

3. Combinations of principal loads, secondary loads and other loads shall in principle be as specified in Table 4-1. The allowable stresses in these cases shall be obtained by multiplying the allowable stresses prescribed in Para. 4-2-1 and 4-2-2 by the factors shown in this table.

Table 4 - 1

	Load Combination	Multiplying Factors
1	$P + T$	1.15
2	$P + L_F$	1.25
3	$P + B$	1.25
4	$P + W$	1.25
5	$P + F$	1.25
6	$P + L_F + W$	1.40
7	$P + B + W$	1.40
8	$P + B + L_R$	1.40
9	$L_F + W$	1.25
10	$W + B$	1.25
11	$B + L_R$	1.25
12	$P + E$	1.70
13	$P + T + E$	1.70
14	E	1.70
15	E	1.30
16	L_R	1.00

Note: The above symbols are shown in Table 2-1.

4-2 Allowable Stresses for Existing Bridge

4-2-1 Allowable Stresses for structural steels

The allowable stresses for members of existing bridges shall be as specified by the following paragraphs.

(1) Axial Stresses (kg/cm^2)

Tensile stress	(in net sections)	1,300
Compressive stress	(in gross section)	$1,200 - 0.05\,(\ell/r)^2$ at $\ell/r \leq 110$ $7,200,000/(\ell/r)^2$ at $\ell/r > 110$

ℓ is the buckling length of the member (cm) and r is the radius (cm) of gyration of the gross section about the axis concerned. How to take ℓ, see Table 4-2.

(2) Bending Stresses (kg/cm^2)

Tensile extreme fiber stress (in net section)	1,300
Compressive extreme fiber stress (in gross section)	$1{,}200 - 0.5\,(\ell/b)^2$ at $\ell/b \leq 30$
Tensile and compressive fiber stress of pin	1,900

ℓ is the distance (cm) between the fixed points of the flange, b is the width (cm) of the flange of I-section girder.

Table 4 - 2

Kinds of Members	ℓ
Chord Members of Truss	Length between connection centers
Web Members of Truss (For the buckling out of the plane of the truss)	Length between connection centers
Web Members of Truss (For the buckling in the plane of the truss)	0.9 times of the length between connection centers
Lateral Bracing Members and Sway Bracing Members and Diagonal Members	Length between connection centers

(3) Shearing Stresses (kg/cm^2)

Steel plate (in gross section)	800
(in net section)	1,000
Shop rivet and Pin	1,000
Field rivet and Ordinary bolt	800

(4) Bearing Stresses

Rivet hole bearing stress	
for Shop rivet	2,200
for Field rivet	1,800
Pin hole bearing stress	1,600
Bearing stress between plates	2,000

4-2-2 Allowable Fatigue Stresses

The allowable stresses of structural steel and for rivet in the checking of fatigue strength shall conform to the values given in the following paragraphs. In the formulas, k is the ratio of the minimum value to the maximum value of stress caused by the principal loads, that is,

$$K = \frac{|\sigma|\ min.}{|\sigma|\ max.} \ \text{or}\ \frac{|\tau|min.}{|\tau|max.}$$

with positive sign for the stress fluctuating in either of tension or compression only, and negative sign for the stress fluctuating between tension and compression.

(1) Allowable Fatigue stresses for Base Metal of Structural Steel (in kg/cm^2)

For tensile stress $\frac{1,275}{1-0.7K}$, but smaller than 1,300

For compressive stress $\frac{1,575}{1-1.1K}$, but smaller than 1,200

(2) Allowable Fatigue Stresses for Rivets

Shearing Stress

For shop rivet $\frac{1,020}{1-0.7K}$, but smaller than 1,000

For field rivet 80% of shop rivet

Bearing Stress

For shop rivet $\frac{2,200}{1-0.7K}$, but smaller than, 2,200

For field rivet 80% of shop rivet

4-3 Allowable Stresses for Structural Steel used for Improvement

The allowable stresses for structural steel and rivet to be used for steel bridges for repair, strengthening and replacement shall be in conformity to Specifications for Designs, JNR, Para. 4-2 to 4-4.

4-4 Allowable Bearing Stress for Concrete

The allowable bearing stress for concrete of shoe base shall be in principle $40kg/cm^2$, provided that it is allowed to be increased in cases where special consideration is made in the construction measures.

CHAPTER V. GENERAL PROVISIONS FOR DESIGN

5-1 Elastic Constants of Steel

Elastic constants of steel shall be of the values of given in Table 5-1.

Table 5 - 1

Young's Modulus	E	2,100,000 kg/cm^2
Shear Modulus	G	810,000 kg/cm^2
Poisson's Ratio	ν	0.3

5-2 Width of Bridge

The width of bridge shall be usually larger than 1/20 of its span.

5-3 Deflection of Bridge

As much efforts shall be made as possible to keep the deflection of the main girder or truss within the value set by Table 5-2 except in special cases. In this case, the train load shall be taken on single track, and no impact may be taken into account.

Table 5 - 2

Types of Bridge	Deflection Due to Train Load
Plate Girder	L/ 800
Truss	L/1,000

where: L is the span length.

5-4 Slenderness Ratio of Structural Members

The slenderness ratio ℓ/r of structural members shall not exceed the values given in Table 5-3. With respect to the definition of ℓ and r, Par. 4-2-1 shall be referred to.

Table 5 - 3

Kind of Members	Slenderness Ratio
Main Compressive Members	100
Secondary Compressive Members	120
Tensile Members	200

5-5 Thickness of Steel

The minimum thickness of steel material shall be specified in the following paragraphs.

(1) With regard to main members, the minimum thickness shall be as a rule 9mm, but orthotropic deck plate shall be 12mm or thickner while buckle plate 8mm or thickner.

(2) The minimum thickness of secondary members shall be as a rule 8mm, but this shall not apply to materials for fillers, protection plates and handrails.

5-6 Minimum Size of Angle Steel Bars

The minimum length of legs of angle steel bars to be used for lateral bracing, brake truss and sway bracing shall be 75mm.

5-7 Camber

A bridge with a span of more than 30m shall have a camber. The camber shall be such an amount as to offset the deflection of the main girder or truss when a uniform load equal to 1/3 the uniform load of DL-15 Loading specified in Par. 2-3-1 and the dead load are placed on the entire length of the main girder.

CHAPTER VI. CALCULATION FOR DESIGN OF MEMBERS AND CONNECTIONS

6-1 Rivet Hole and Bolt Hole

The diameter of a rivet hole or a bolt hole for the calculation of net sectional area of a structural member shall be 3mm larger than the nominal rivet or bolt diameter.

6-2 Calculation of Net Sectional Area

The net sectional area of a tensil member shall be the product of the net width of plate and its thickness. The net width of a component piece shall be the remainder obtained by deducting some of the diameters of rivet holes or bolt holes from the gross width.

6-3 Effective Sectional Area of Tension Angle Members

In the case of a tension member consisting of one or two angle steel bars, if it is connected in such a manner as to undergo no bending moment due to eccentricity, its full sectional area shall be regarded as effective. In case it is connected in such a way that a bending moment is caused on the member due to eccentricity, as shown in Fig. 6-2, the net sectional area of the leg connected with the gusset plate plus half the gross sectional area of the other leg shall be considered as effective.

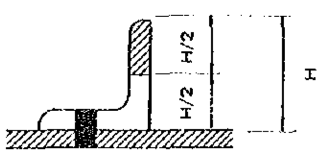


Fig. 6-2

6-4 Effective Sectional Area of Compression Members

The effective sectional area of compression members constructed and connected with weld, rivet or high strength bolts shall be equal to its gross sectional area, but that of a compression member having ordinary bolts or pins shall be the area in which the area equal to the sum of diameters of holes for bolts on pins multiplied by the plate thickness is deducted from the gross sectional area.

6-5 Effective Sectional Area When Deflection and Statically Indeterminate Force are to be Calculated

The effective sectional area when deflection and statically in determinate force are to be calculated shall be equal to the gross sectional area.

6-6 Bending Stress of Members

The stress due to bending moment of plate girders and similar structures shall be calculated in accordance with the following paragraphs.

(1) Stress due to bending moment

$$\sigma = \frac{M}{I} \cdot y$$

(2) Extreme fiber stress due to bending moment

$$\sigma_c = \frac{M}{I} \cdot y_c \quad , \quad \sigma_t = \frac{M}{I} \cdot y_c \cdot \frac{Afg}{Afn}$$

where. σc is the actual compressive stress (kg/cm^2)
σt is the actual tensile stress (kg/cm^2)
M is the bending moment (kg · cm)
I is the moment of inertia (cm^4)
Yc and Yt are respectively the distance (cm) from the neutral axis to the position of the calculation on the compressive and tensile sides.
Afg and Afn are respectively the gross sectional area and net sectional area (cm^2) of the flange to be checked.

6-7 Checking of Stress of Members Subjected to Both Axial Force and Bending Moment

A member subjected simultaneously to a force in the axial direction and a bending moment shall conform to requirements of Par. 4-1 and 4-2 respectively regarding each of them and shall be checked by the following formulas also.

(1) When the axial force is tensile:
Regarding stress intensity

$$\frac{P}{An} + \frac{Mx}{Ix} \cdot y_t \cdot \frac{Afg}{Afn} \leqq \sigma ta \qquad (1)$$

(2) When the axial force is compressive:
Regarding stress intensity

$$\frac{P}{A_g} + \frac{M}{I_x} \cdot Y_c \leqq \sigma ca \qquad (2)$$

where; P is the axial force (kg)
An and Ag are respectively the net sectional area and gross sectional area (cm^2) of the section to be checked.
σ ta and σ ca are the basic allowable tensile and compressive stress (kg/cm^2) specified by Par. 4-2. with regard to others refer to Par. 6-6.

6-8 Shearing Stress of Members

1. The Average shearing stress of web plate of a plate girder or a similar structure shall be calculated by the following formula.

$$\tau = \frac{S}{Aw}$$

where; τ is the average shearing stress (kg/cm^2) acting on the web plate.
S is the shearing force (kg)
Aw is the gross sectional area (cm^2) of the web plate.

6-9 Connection of Members

1. The connection of members with rivets, high-strength bolts or by welding shall in principle be designed on the basis of calculated actual stress, but with regard to a butt joint with groove weld, the whole section shall be welded.

2. In addition to the preceding paragraph, connection for main members shall be designed with due care to give at least 75% of the member strength based on the basic allowable stress intensity for tension members or on the buckling allowable

stress intensity for compression members. (When the members are subject to both tension and compression, take the allowable stress of the same sign as the larger member stress of the two).

3. Connection of members shall be so designed as to minimize the eccentricity in each component pieces.

6-10 Stringer

1. The span length of a stringer taken for design calculation shall be as a rule the distance between the centers of floor beams.
2. A stringer shall by preference be designed in a continuous structure.
3. In case stringers continue for more than 75 meters in total length, an expansion device shall be provided at about the middle of the bridge if practicable.

6-11 Floor Beam

1. Floor beams shall be arranged at a right angle to the main truss or girder as much as practicable.
2. The span length of a floor beam used in design calculation shall be in principle equal to the distance between the centers of main trusses or girders on both sides.
3. It shall be a rule to install floor beams also at the ends in a through plate girder bridge.
4. The end floor beams shall be designed to be strong enough for jacking-up of the bridge as much as practicable. In regard to the increase of allowable stresses in this case, the value for erection load as prescribed in 4-1 shall be used.

6-12 Connection between Stringers and Floor Beams

In the connection between stringers and floor beams at their webs, only shearing force shall be taken into consideration as a rule; and a value 1.2 times as large as the reaction force obtained when the stringer is calculated as a simple beam shall be used, whether the stringer is a continuous beam or a simple beam. The allowable stresses for the rivets and high-strength bolts in this case shall conform to the basic allowable stresses.

6-13 Connection of Floor Beam with Main Girder

In a through plate girder bridge, the web of the floor beam shall in principle be connected with the web plate of the main girder by the medium of its stiffener and a connection angle and fastened with rivets or high-strength bolts. The lower flange of the floor beam and the lower flange of the main girder are preferably connected by the medium of a gusset plate.

6-14 Types of Weld

1. For welded joints that is intended to transmit stresses, groove weld or continuous fillet weld shall be employed.
2. Intermittent weld, plug weld or slot weld shall not be used for the fabrication of main members.

6-15 Effective Length of Weld

1. The effective length of weld used in stress calculation of welded joint shall be the

the length of welded part whose throat thickness conforms to the requirement of the design.

2. In case the weld line in groove weld is not perpendicular to the direction of stress, the effective length shall be the length of actual weld line projected on a line perpendicular to the stress direction.

3. In the case of fillet weld, when the weld is extended around the corner, such extended welded part shall not be included in the effective length.

6-16 Groove Welded Butt Joint

1. In a butt joint of groove weld the entire cross-section of the piece shall be welded and the member shall be of such a construction as to permit a back weld. In case the back weld is unpracticable because of an unavoidable structural reason, backing strips shall be used instead.

2. In a butt joint between plates of different sectional dimensions, the thickness and width shall be changed gradually in a lengthwise slope not exceeding 1/5.

CHAPTER VII. STRUCTURAL DETAILS

7-1 Bracing Members

1. Built-up members or shape steels shall be used for lateral bracings, brake trusses and sway bracings, and in case these members cross each other, they shall be connected with each other at their intersecting point.

2. For long bracings, solid-web construction shall be preferably adopted if practicable.

7-2 Lateral Bracings

1. Upper and lower lateral bracings shall be provided as a rule. However, with respect to a through plate girder bridge, only lower lateral bracings shall be used and furthermore in the case of closed floor bridge with a strong floor system, the lower lateral bracing may be simplified.

2. In regard of a deck plate girder bridge with sufficient sway bracings, lower lateral bracings may be omitted for those with a span shorter than 16m if the track is straight, or with a span shorter than 12m when the track is curved.

3. The lateral bracings between compression chord members of a truss shall be designed to withstand the force specified in Chapter 2 and furthermore to resist the shearing force equal to 1% of the total compressive force on the right and left chord members in the panel under consideration. This shearing force shall be considered as a principal load.

7-3 Brake Trusses

Bridges shall be provided with brake trusses in order to resist longitudinal forces such as braking force, traction force, force due to long-rails if necessary. In this case, for each sets of continuous stringers with no expansion joint, a brake truss shall be installed about the middle of the set as much as practicable.

7-4 Fixing of Upper Flanges of Through a Plate Girder Bridge

1. It shall be a rule that the floor beams of a through plate girder bridge be provided with knee braces on their both ends.

2. When the knee braces are suspected not to be strong enough, they shall be checked according to the following provisions.

   (1) The rigity (k) of the U-form construction composed of a floor beam and vertical stiffeners shall be greater than the value obtained by the formula below.

$$k \geqq \frac{8A\ \sigma ca}{\ell}$$

where; k is the rigidity (kg/cm) of the U-form construction, that is, the horizontal force when $\sigma = 1$ in Fig. 13-3 ($k = K/\sigma$).
A is the cross sectional area (cm^2) of the upper flange (same for (2)).
σca is the allowable compressive stress (kg/cm^2) in bending of the main girder.

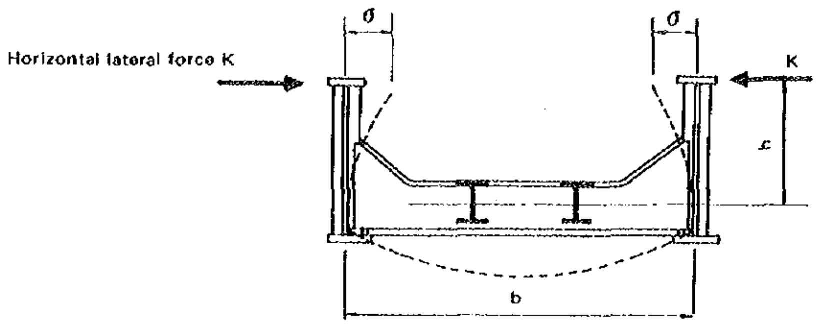


Fig. 13 - 3

ℓ is the assumed buckling length of the main girder flange (cm).

(2) The construction referred to above must have also a sufficient strength to stand the horizontal lateral force of the magnitude given by the following formula, acting on the tops.

$$H = \frac{A\ \sigma c}{100}$$

where; H is the horizontal force (kg) applied for checking the strength.
σ_c is the bending extreme-fiber compressive stress acting on the upper flange (kg/cm^2).

7-5 Thickness of Gussets of Main Truss

In the construction of main truss or other similar structure, when two gussets are used in pairs to connect a web member with a chord member, the thickness of each gusset plate shall be advisably larger than the value calculated by the formula below and larger than 11mm.

$$t = \frac{22\ P}{b}$$

where; t is the thickness of the gusset plate (mm)
P is the maximum force (t) acting on one of the members connected with the gusset.
b is the width of the plate of the said member which is in contact with the gusset (mm).

7-6 Pony Truss

The U-form construction composed of a floor beam and vertical stiffeners shall have the rigidity and strength specified by Para. 2 of 7-4, but in this case the values of upper chord members instead of upper flanges shall be used.

APPENDIX II

MANUALS FOR EXECUTION OF THE WORKS

*Reference literature
Criteria of shop painting of JNR
(Fabrication of Steel Railway Bridges 1971)

CHAPTER I. GENERAL

These manuals shall be applied to the improvement works for steel bridges of the State Railway of Thailand. For fabrication of steel bridges "Specification for the supply of steel superstructure of railway bridges (meter gauge) B.E. 2518" shall be, in principle, adopted.

Rivet and high-strength bolt shall be specified by the following provisions.

CHAPTER II. RIVET JOINT AND BOLT JOINT

1. Rivet Holes and Bolt Holes

1-1 The hole shall be cylindrical and its axis unless otherwise specified in the drawing shall be perpendicular to the surface of the plate and the allowable amount of inclination shall be less than 1/20.

1-2 The diameters of rivet holes and bolt holes shall conform to the values in Table 1.

Table 1. Rivet and Bolt Hole Diameters

Nominal Rivet Diameter	Nominal Bolt Size		Diameter of Hole (mm)
25	W 1		27.8
		M 24	26.5
22	W 3/8	M 22	24.5
		M 20	22.5
19	W 3/4		21.5
16	W 5/8	M 16	18.0
13	W 1/2		15.0
		M 12	14.0

1-3 The hole shapes for counter-sunk rivets, counter-sunk interference-body high-strength bolt and ordinary counter-sunk bolts shall conform to Fig. 1 and Table 2.

The hole diameter for the portion of shank of rivet and bolt (cylindrical part) shall conform to Par. 1-2.

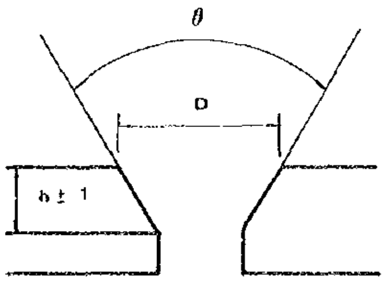


Fig. 1 Shape of Counter-sunk Rivet and Counter-sunk Bolt

Table 2. Dimensions of Holes for Counter-sunk Rivets and Counter-sunk High-strength Bolts

Counter-sunk Rivets				Counter-sunk Interference-body High-strength Bolts				Ordinary Counter-sunk Bolts			
Nomin. Dia.	θ	h (mm)	D (mm)	Nomin. Size		h (mm)	D (mm)	Nomin. Size	θ	h (mm)	D (mm)
25		13.5	42.4					M 24	60°	15.0	43.1
22	60°	12.0	37.3	M 22		11	35	M 22		14.2	39.9
19		10.5	32.6	M 20	60°	10	32	M 20		9.5	40.5
16		9.0	27.4	M 16		8	25	M 16	90°	8.5	34.0
13	75°	6.0	22.2					M 12		7.5	28.0

1-4 Holes in main members shall be made by drilling to the specified diameters, or preparatory holes of a smaller diameter shall be drilled at first, and after steel pieces are assembled, they shall be enlarged to the specified diameter by reaming, or duplicating process for drilling shall be employed.

1-5 Holes in secondary members may be made by punching to the specified diameters, but holes in steel pieces more than 16mm thick shall be made as specified by Par. 1.4. Rivet or bolt holes for connection with main members shall also conform to Par. 1-4.

1-6 Processing around rivet holes and bolt holes shall be done as instructed in the following provisions.

(1) Burrs around the hole edge formed in the course of drilling shall be scraped off.

(2) The edge of the hole in contact with the head of field rivet shall be chamfered as a rule at 0.5mm.

(3) Relief roll marks in the neighbourhood of rivet holes and high-strength bolt holes shall be removed, but this may not be applicable in the case of ordinary bolts.

1-7 Passing drift pins through holes in assembly work shall be done just for drawing steel pieces up to each other without excessive force, and care shall be taken not to damage the holes.

1-8 The tolerance for rivet hole and bolt hole measurement shall conform to the requirements of Table 3 except the case specified by the design drawing. With respect to the tolerance when a gusset plate is fitted to a main member, the provisions for main members shall apply.

The go-gauge shown in Table 4 shall be able to pass through holes after the members have been assembled.

Table 3. Tolerance for Hole Diameter (mm)

Fasteners / Members	Rivets and Ordinary Bolts	High-strength Bolts	Interference-body High Strength Bolts
Main Members	+0.8 (but +1.2 for 20% of a group) and -0.4	+0.5 (but +1.0 for 20% of a group)	± 0.3
Secondary Members	+1.2 and -0.4		

Table 4. Go-Gauge

Nominal Rivet Diameter (mm)	High - strength Bolts		Go-Gauge (mm)
	Nominal Whitworth Size	Nominal Metric Size	
25	W 1		26
		M 24	25
22	W 7/8	M 22	23
		M 20	21
19	W 3/4		20
16	W 5/8	M 16	16.5
13	W 1/2		13.5
		M 12	12.5

(Note) Gauges of 22.4mm and 20.4mm in diameter shall pass and gauges of 23.5mm and 21.5mm shall not pass the holes for M 22 and M 20 of interference-body, high-strength bolts respectively.

2. Quality of Rivet and High-strength Bolt

The quality of rivets and high-strength bolts shall conform to the requirements of Table 5 and also to the following provisions.

(1) The shank length of a rivet must be large enough to fill up the rivet hole and to form the head of the specified shape.

(2) The shank length of a bolt shall be selected so that at least three threads may protrude beyond the nut face after tightening.

(3) The length of the cylindrical part of an interference-body high-strength bolt shall be larger than the fastened length minus 3mm.

3. Riveting

3-1 In case steel pieces are riveted, the surfaces to come in contact with each other shall undergo the following treatments.

(1) Clear the surface of rust and clean it before assembly.

(2) The contact surfaces shall not be coated with paint, but the pretreatment coating may remain.

3-2 In riveting, the assembled steel pieces must be sufficiently clamped with bolts and drift pins so as to leave no gap between the pieces.

3-3 The rivet shall be heated evenly in its entirety, cleared of sticking dust and applied quickly preferably with a jaw riveter. Care shall be taken not to damage the rivet head and thereabout in the work.

3-4 The driven rivet shall tightly fill up the rivet hole without any looseness. The rivet head must be of the prescribed shape with no pits, no cracks and no "brim," positioned concentrically with the rivet shank and the edge of its head shall be in tight contact with the surface of the plate.

3-5 Rivets not conforming to the requirements of 3.4 shall be removed and thereafter riveting shall be carried out all over again. The removal of the defective rivets shall be done by drilling as a rule with due care not to damage the base metal and not to loosen other rivets around.

3-6 As a means to correct a loose rivet, no calking nor hammering shall be done on the rivet after cooling.

Table 5. Materials for Connection

Items	Standards
Rivets	JIS G3104 (Rolled Steel for Rivets) of which SV34 and SV41A are applicable. JIS B 1214 (Hot-Formed Rivets)
High-Strength Bolts	JIS B 1186 - 1970 (Sets of High-Strength Hexagonal Bolts. Hexagonal Nuts and Plain Washers for Frictional Grip Joints)
Bolts	JIS B 1180 (Hexagonal Bolts)
Nuts	JIS B 1181 (Hexagonal Nuts)
Screw Thread	JIS B 0205 (Metric Coarse Threads) JIS B 0206 (Whitworth Coarse Threads and Unified Coarse Threads) JIS B 0207 (Metric Fine Threads) JIS B 0213 (Tolerance of Metric Thread Pitches and Tolerance of Half Angle of Thread) JIS B 0214 (Tolerance of Whitworth and Unified Thread Pitches and Tolerance of Half Angle of Thread)

Driving-Fit High-Strength Bolts	JIS 57605-4 (Sets of Driving-Fit High-Strength Bolts, Hexagonal Nuts and Plain Washers)
Notes: JIS G;	Japanese Industrial Standards Ferrous Materials and Metallurgy (1976)
JIS B;	Japanese Industrial Standards Screw (1976)
JRS ;	Japan Railway Standards Fabrication of Steel Railway Bridges (1971)

4. Fastening of High-strength Bolts

4-1 The contacting surface and thereabout of the steel pieces to be connected with high-strength bolts shall be subjected to the following treatment.

(1) Rust and mill scale shall be removed by blasting or other appropriate processes.

(2) The standard surface roughness shall be 50S of the grade specified by JIS B 0601 (Surface Roughness).

(3) On no account shall a coating be done with preparatory paint, red lead rust-preventing paint, etc.

(4) In case preparatory paint has been applied to the plate before cutting, it shall be removed with blasting, flame-cleaning, wire-brushing, etc.

4-2 Examination for torque value of bolt shall be conducted as a rule immediately before starting work, and from the mean value of the examination the value for obtaining the required axial force of bolts shall be determined. The bolts which have been used for the examination can be used for actual structural members except those utilized frequently for the calibration of the fastening tools.

4-3 The standard fastening axial force of the bolt shall conform to the values of Table 6. Excessively small or large fastening axial force shall be avoided.

Table 6. Fastening Axial Force of Bolts

In the Case of Bolts of JIS B 1186 - 1964 (Whitworth Screw Thread)

Nominal Size	Axial Force of Bolt in Tons	
	F9T	F11T
W 1	22.3	30.4
W 7/8	17.0	23.1
W 3/4	12.3	16.7
W 5/8	8.8	11.9

In the Case of Bolts of JIS B 1186 - 1970 (Metric Screw Thread)

Nominal Size	Axial Force of Bolt in Tons		
	F8T	F10T	F11T
M 24	21.1	26.2	27.6
M 22	18.2	22.5	23.8
M 20	14.7	18.2	19.2
M 16	9.4	11.6	12.3

4-4 In regard of washers to be used in pair, one washer shall be employed at the bolt head and the other one at the nut.

In case a washer with lubricative surface treatment to decrease the torque value is to be employed, this type of washer shall be used under the nut only and a washer without the surface treatment shall be used under the bolt head.

4-5 In fastening bolts, start from the middle part of the bolt group advancing toward end bolts, fastening one by one in due sequence of order. At first tighten all the bolts up to about 80% of the required torque; then at the second round of fastening give them the prescribed torque.

4-6 With regard to high-strength bolts for secondary members, the following process may be resorted to despite the prescription of 4.2. Namely, the bolts can be tightened to be utmost of human strength with an ordinary assembly spanner; then with a longer spanner or by some other means, tighten the bolts, furthermore, till the nuts are therefrom turned by $120° \pm 30°$

4-7 In the case of fastening an interference-body high-strength bolt, the bolt shall be driven in by a hammer to such an extent that a nut can just seize the thread, then the bolt shall be drawn in by turning the nut. The process for fastening the bolts thereafter shall be carried out in the same manner as described in 4-6.

CHAPTER III. GENERAL NOTES FOR EXECUTION OF FIELD WORKS

1. Handling of Members

Care should be taken not to bend nor injure the plates or angles used for repair and strengthening in unloading from freight cars and in assembly.

2. Stagings

2-1 Stagings for work should be rigid and strong enough.

2-2 The structure of staging should have sufficient height and width for working posture.

2-3 Stagings should not be subjected to an excessive load.

3. Drilling of Holes

3-1 Making-off and punching should be effected accurately by using the same band scales and templates as used in the factory fabrication.

3-2 Drilling of the additional members should be effected by checking the position of attachment and firmly fixing the additional members to the members to be strengthened.

3-3 Fixing Method

(a) Clamping with use of vices.

(b) Clamping with use of 19ϕ bolts through sub-drilled holes (20.5ϕ) provided At both ends and middle portion of a member.

(c) The additional members may be temporarily fixed by welding of about 40mm in length for each weld in cases where no fear of fatigue is anticipated.

3-4 Drills should be applied at a right angle in relation with the member face.

3-5 Corner drills should be used in the place where ordinary drills cannot be applied.

3-6 Burrs at the periphery of holes drilled should be removed by a scraper.

4. Removal of Old Rivets

4-1 In principle, a gas cutting apparatus must not be used for cutting rivets.

4-2 The procedure of cutting rivet is as follows.

(a) Removal of the head of rivet on one side.

(b) Removal of the shank and the head of rivet on the other side.

4-3 Rivet head on the side should be removed either by breaking the head into two pieces with use of a chipping hammer, or by drilling to an Extent of the height of the head and then striking it with a hammer.

4-4 The remaining portion of the rivet should be removed either by using a hammer and a pin or by drilling therethrough.

4-5 Corner drills should be used for the place where ordinary drills cannot be used.

5. Treatment of Surfaces of Members to be Connected by High-Strength Bolts

The surfaces of members in contact with the connection by high-strength bolts should be, in principle, cleaned beforehand. In cases where no cleaning can be effected for structural reasons or for lack of time allowed for the work, this fact should be taken into consideration in designing stage to increase the number of bolts.

5-1 Degree of Cleaning

Rust and paint should be thoroughly removed (Cleaning Grade 2).

5-2 Methods for Cleaning

(a) Mechanical treatment

(b) Flame cleaning

(c) Chemical treatment

5-3 Mechanical Treatment

Cleaning should be, in principle, carried out by using air angle grinders, scrappers or wire brushes.

5-4 Flame Cleaning

In cases where the mechanical treatment cannot give good results because old coatings is tight, the gas flame cleaning method should be employed, followed by wire brush finishing.

5-5 Chemical Treatment

The chemical treatment should be employed for the place where sufficient time is allowed for work or the mechanical treatment is difficult to apply. In employing the chemical treatment, the prescription of the stripping agent should be carefully observed.

5-6 Treatment after Cleaning

Members should be attached and fixed by high-strength bolts immediately after the completion of cleaning, since otherwise rust can again develop.

If any rust has developed, cleaning should be carried out again.

6. Tightening of High-Strength Bolts

High-strength bolts should be tightened on completion of cleaning and attaching of members.

6-1 Temporary Tightening

To attach the members tightly, the members should be temporarily fixed with each other by fitting-up bolts and drift pins of the number corresponding to not less than one-third of the holes for the high-strength bolts.

In case where gap of not less than 2mm still remains after tightening at joing portions, tightening should be again carried out after inserting filler plates.

6-2 Method for Clamping

In using an ordinary shape of high-strength bolt, the control of clamping force should be usually effected by:

(a) Torque control method
(b) Turning angle control method

The control should be conducted mainly by the torque control method. The turning angle control method should be used only in the case where clamping machine can not be used. However, both method must not be mixed in one group of connection. The operator should be sufficiently skilled in handling of the machines.

6-3 Calibration of Clamping Machine

Preliminary check should be performed before using clamping machines to assure if a required value of torque can be maintained.

6-4 Handling of Bolts to be Used

(a) Use should be made of those bolts which have a strength conforming to the design.

(b) Use should be made of those bolts which have a length suitable for the total thickness of the members to be assembled.

(c) Bolts should be stored in a warehouse free of harmful moisture so that the bolts may not be rusted or contaminated.

(d) In using bolts, only the number of bolts required for work at a time should be taken out of the warehouse, and the excess of the bolts remaining after the work should be carefully returned to the warehouse.

(e) Washers should be used for both sides of the assembled members, taking care to apply the lubricated washers to the nut side, and the ordinary ones to the bolt-head side.

(f) Any hammer should not be used for inserting bolts.

6-5 Procesures for Clamping

Clamping should be effected, beginning at the middle portion and extending to right and left symmetrically.

6-6 Preliminary Clamping

All of the bolts should preliminarily be clamped with an axial force of approximately 80% of the required torque value, and then a linear paint mark should be drawn across the thread, nut, washer, and member.

After the preliminary works, the final clamping force should be given them.

Then the linear mark should be checked for the deviation of the mark produced by the final clamping. The condition of the deviation will serve as an indication of possibility of any mistake of tightening and turning of the bolt together with the nut.

6-7 Inspection

Finally, inspection should be performed to assure if the required torque value has been given or not.

The processes of completion of high-strength bolts, preliminary clamping, final clamping and inspection should be completed within one day.

7. Rivet

7-1 Fitting-up of Members

Procedures before riveting should be much the same as in the case of high-strength bolt joints.

7-2 Machines to be used (in the case of rivet diameter of 22mm)

(a) Air compressor

Air compressors supplying compressed air of 6 - 7 kg/cm^2 in pressure should be provided.

(b) Pneumatic rivet hammer

Rivet hammers having a stroke of piston of approximately 150mm should be provided.

(c) Jam riveter

Pneumatic rivet hammers require a space not less than 600mm because of their size. In case the space is smaller than 600mm, jam riveters should be used.

(d) Receiver (bucker)

A receiver of rivet head from the back side worked by compressed air (pneumatic bucker) should be used, in principle, in rivetting. In case a space is smaller than 200mm, a manual receiver may be used by applying a lever. In using the latter, the work should be conducted especially carefully to make sound rivets.

(e) Snap

A snap which has an air vent at the center should be used in the pneumatic riveter.

7-3 Heating of Rivets

(a) In principle, an oven using coke should be employed in the field for heating rivets.

(b) The coke oven should be installed in the vicinity of the place where riveting work is carried out.

(c) Those rivets having a length adjusted to the total thickness of plates to be fixed by the rivets should be used.

(d) The entire rivet should be uniformly heated to yellowish orange at a temperature of approximately 900°C - 1,100°C, taking care not to heat it deficiently or excessively.

(e) Any scale attached to the heated rivets should be removed before inserting them into holes.

(f) Rivets which were once heated and cooled should not be reused.

7-4 Riveting Work

(a) Riveting should be completed before the temperature of the heated rivets falls excessively by promptly carrying out the following four processes:

(1) Heating of rivet
(2) Insertion of rivet
(3) Application of bucker
(4) Application of riveter

(b) A rivet hammer should be applied straight in relation with the rivet axis and should not be turned until the rivet has been fully charged in the hole.

(c) A rivet hammer should be turned only at the final stage when the head is to be finished to a prescribed shape.

(d) For members wetted by rain, etc., riveting should not be carried out until they are dried.

7-5 Inspection

The following items should be inspected:

(a) Tightness of finished rivet (hammering inspection).

(b) Roughness of the head of rivet due to excessive heating.

(c) Inadequate shape of the rivet head due to deficient heating.

(d) Inadequate shape of the rivet head due to the use of inappropriate length of rivet.

(e) Eccentricity between the rivet head and the rivet shank.

(f) Crack at the edge of the rivet head.

(g) Opening at the edge of rivet head of the receiver side.

The rivets found to be defective by the inspection should be replaced by new rivets. In removing such rivets, a drill should be used instead of gas flame as in the case of removal of old rivets.

8. Installation of Shoes

8-1 In order to prepare anchor bolt holes, an accurate measurement as to position and depth should be made before installing shoes.

8-2 Steel wedges for adjusting the level of a shoe should be removed after charging mortar to the underside of the shoe.

The void portions resulting from removal of the steel wedges have been removed should be charged also with mortar afterwards.

8-3 Non-shrinkage mortar should preferably be used for filling the underside of a shoe, taking care not to leave any void in the applied mortar.

basic surface treatment described in Par. 1 and thereafter coated with JRS 66062-2C-13ARIC (Preparatory Paint for Long Period) at the rate of more than $100g/m^2$; no undercoating shall be applied.

6-7 Shoes, washers and anchor bolts, unless otherwise specified in the design drawing, shall be treated and painted in the same way as prescribed in Par. (3). No paint shall be applied to the bottom of the shoe and the part of an anchor bolt, lower than a point of 50mm below the top face of the concrete pier or abutment.

6-8 The rollers and the rolling faces of a roller shoe shall be coated with JRS 66062-2C-13 ARIC (Preparatory Paint for Long Period) and thereafter under-coating prescribed in Par. 1 shall be applied.

6-9 In the case of a shoe with copper alloy sliding plate, the sliding plate and the face of the shoe brought to contact with the sliding plate shall not be painted.

6-10 Rust-Preventing grease shall be applied to the pin, the finished surface of pin hole, the threaded bolt hole and the threaded part of anchor bolt.

6-11 The inside surfaces of an incompletely closed box type member shall be coated in accordance with the painting process and the standard quantity of consumption prescribed in Table 8.

However, the conditions for airless blowing or tar epoxy resin paint shall conform to Table 9.

REFERENCE LITERATURE

Criteria of shop painting of JNR.
(Fabrication of Steel Railway Bridges 1971)

1. Members of a bridge shall be painted in accordance with "Process of Painting and Standard Quantity of Paint to be Used" shown by Table 7 with the exception of cases falling under Par. 6.

Table 7. Process of Painting and Standard Quantity of Paint to be Used

Process	Particulars of Work	
Basic Surface Adjustment	Removal of rust and mill-scale shall be carried out by blasting or pickling. In this process, the limit of surface roughness shall conform to 50S of JIS B 0601 (Surface Roughness).	
Time Elapsed	Less than 3 hours	
Preparatory Coating (either one of the process designated in the right columns)	JIS K 5633-1965 (Etching Primer) applied by brushing at the rate of more than $80g/m^2$, or by airless blowing at the rate of more than $100g/m^2$.	JRS 66062-2C-13ARIC (Preparatory Paint) applied by brushing at the rate of $100g/m^2$, or by airless blowing at the rate of more than $130g/m^2$.
Time Elapsed	1 hr. to 24 hrs.	More than 12 hrs.
1st Layer Under-Coating	JRS 66053-4B-13AROC (Red Lead Rust-Preventing Paint) Grade 1 applied by brushing at the rate of more than $200g/m^2$, by airlegs blowing at the rate of more than $250g/m^2$.	
Time Elapsed	48 hrs. to 7 days	
2nd Layer Under-Coating	JRS 66053-4B-13AROC (Red Lead Rust-Preventing Paint) Grade 2 applied by brushing at the rate of more than $180g/m^2$, or by airless blowing at the rate of more than $230g/m^2$. Color should be changed slightly from 1st layer painting.	

Note: If the paint is felt wet by finger even After lapse of 48 hours, the time must be lengthened.

2. The surface to be painted shall be cleaned of dust, oil, white powder used for making-off and moisture prior to coating.

3. When a steel plate which was coated in "preparatory paint for long period" before the cutting process has got rusty or the coating has deteriorated, the rusty parts shall be cleaned and painted for repair. The scale formed on the weld bead surface, shop vivet heads and high-strength bolt heads shall be removed by blasting and other appropriate means and the part shall be subjected to preparatory coating.

4. In under-coating, the member shall not be exposed to rain or dew before 24 hours has elapsed after each time of finish of the first and second layer paintings.

5. The painted surface shall be of the following conditions.

(1) The painted surface shall be smooth.

(2) There shall be no conspicuous brush marks, no irregular flows, nor remarkable unevenness.

(3) There shall be no such defects as remarkable swelling, discolorment, blurs, chalking, etc.

(4) There shall be none of cracks, pits and pin holes on the paint coating.

6. Contact surfaces and inner surfaces of a box girder bridge shall be painted in conformity to the following provisions.

6-1 In case steel pieces are riveted, the surfaces to come in contact with each other shall undergo the following treatments.

(1) Clear the surface of rust and clean it before assembly. However, this need not conform to the basic treatment provided for by Par. l.

(2) The contact surfaces shall not be coated with paint, but the pre-treatment coating may remain.

6-2 The contacting surface and thereabout of the steel pieces to be connected with high-strength bolts shall be subjected to the following treatment.

(1) Rust and mill scale shall be removed by blasting or other appropriate processes.

(2) The standard surface roughness shall be 50S of the grade specified by JIS B 0601 (Surface Roughness).

(3) On no account shall a coating be done with preparatory paint, red lead rust-preventing paint, etc.

(4) In case preparatory paint has been applied to the plate before cutting, it shall be removed with blasting, flame-cleaning, wire-brushing, etc.

6-3 Side walks, filler plates and drainage facilities shall be cleared of rust and dirts and painted with one layer of JRS 66053-4B-13AROC (Red Lead Rust-Preventing Paint) Grade 1. In this respect, the basic surface adjustment and the preparatory coating prescribed in Par. 1 can be omitted.

6-4 The inside surfaces of a completely enclosed construction shall be cleared of rust with hand scraper or the like and cleaned, but painting can be omitted on them.

6-5 The bevel edges of main members for field welding shall be coated with a paint of rust preventing effect but as little detrimental effect on weld as possible. No under-coating shall be applied.

6-6 The surface on which water-proof layer is to be applied shall as a rule be subjected to

Table 8. Process of Painting Inside Surfaces of Box Type Cross-Section Members and Standard Quantity of Paint

<table>
<tr><th>Process</th><th colspan="2">Particular of Work</th></tr>
<tr><td>Basic Surface Adjustment</td><td colspan="2">Remove rust and mill-scale by blasting or pickling.
In this process, the limit of surface roughness shall conform to 50S of JIS B 0601 (Surface Roughness).</td></tr>
<tr><td>Time Elapsed</td><td rowspan="3">When 1st layer under-coating can be done after the basic surface treatment in the same day, preparatory coating shall be omitted.</td><td>Less than 3 hrs.</td></tr>
<tr><td>Preparatory Coating</td><td>In case what is described in the left column is impossible, or when the plate has been pre-treated before cutting, the inside surface shall be painted with JRS 66062-2C-13ARIC (Preparatory Paint for Long Period) at the rate of more than 100g/m^2.</td></tr>
<tr><td>Time Elapsed</td><td>More than 7 days</td></tr>
<tr><td>1st Layer Painting</td><td colspan="2">JRS 66099-8A-13ARIC (Tar Epoxy Resin Paint) applied by brushing at the rate of more than 250g/m^2, or by airless blowing at the rate of more than 300g/m^2.</td></tr>
<tr><td>Time Elapsed</td><td colspan="2">48 hrs. to 5 days.</td></tr>
<tr><td>2nd Layer Painting</td><td colspan="2">The work shall be done in the same way as in the 1st-layer painting, provided that a paint of different color is to be used.</td></tr>
</table>

Table 9. Conditions in Case Tar Epoxy Resin Paint is Applied by Airless Blowing to Inside Surfaces of Box Type Cross Section Members

<table>
<tr><td colspan="2">Pressure</td><td>5 to 6kg/cm^2</td></tr>
<tr><td colspan="2">Compression Ratio</td><td>1 : 23 or higher</td></tr>
<tr><td rowspan="2">Nozzle Tip</td><td>Rate of spouting</td><td>0.95 to 2.30 lit/min</td></tr>
<tr><td>Pattern Width</td><td>25 to 36cm</td></tr>
<tr><td colspan="2">Moving Speed of Gun</td><td>80 to 100cm/sec</td></tr>
<tr><td colspan="2">Distance Between Gun and Plate</td><td>30 to 40cm</td></tr>
<tr><td colspan="2">Temperature at Painting</td><td>10° to 30°C</td></tr>
<tr><td colspan="2">Thinner</td><td>It is allowed to add 5% of thinner or less if necessary</td></tr>
</table>

7. No painting work shall be performed in the following conditions.

(1) When the temperature in the shop is lower than 5°C. At 10°C or lower as a rule, in the case of tar epoxy resin paint.

(2) In rainy weather except for indoor work.

(3) At a relative humidity of 80% or higher.

(4) When dusty wind blows.

(5) As a rule, within 3 hours from the sunrise and within 3 hours to the sunset. But this is not applicable to indoor work, and the above rule shall be adjusted by taking into consideration drying and dew formation.

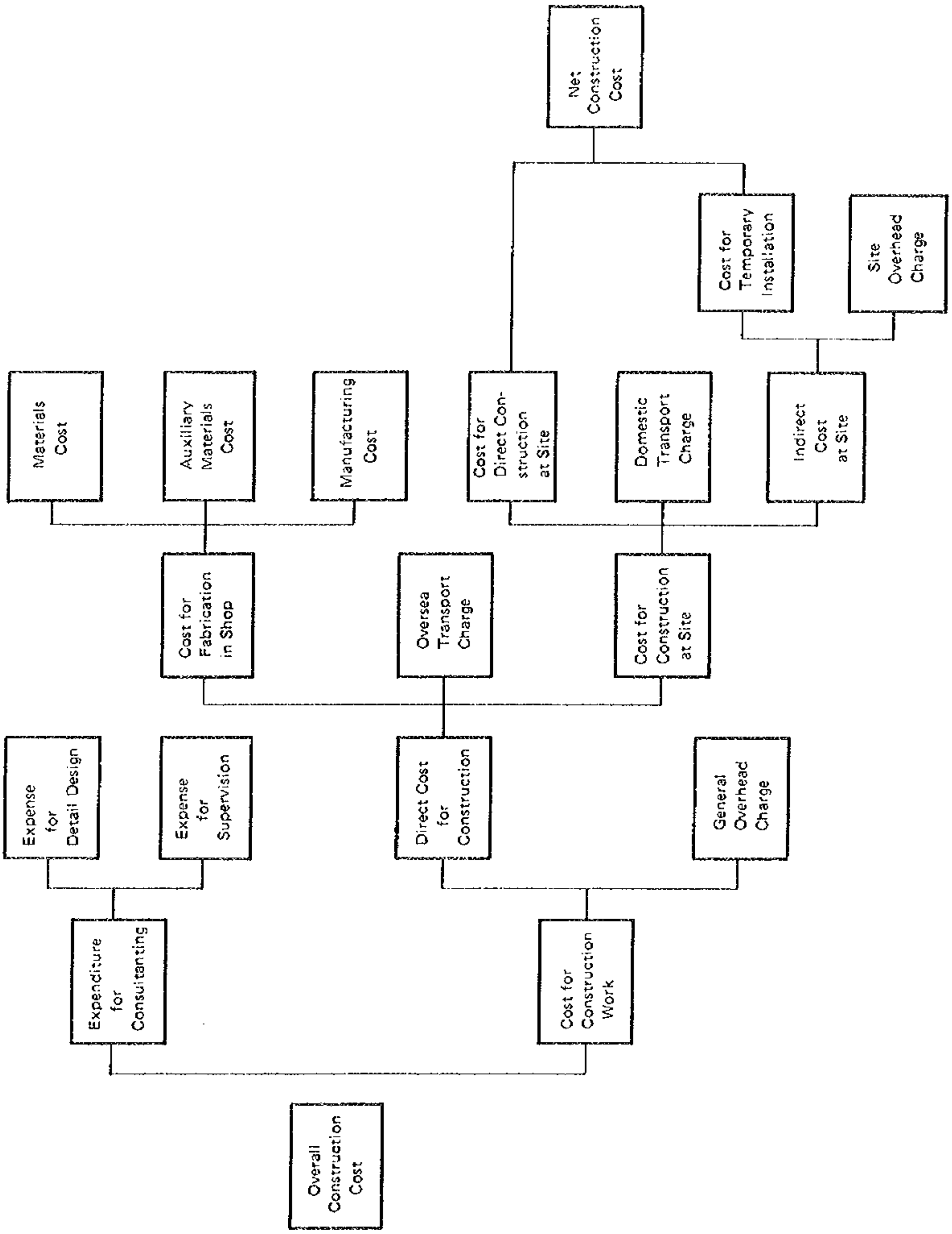
APPENDIX III

METHOD FOR COST ESTIMATION

CONTENTS

1. Composition of Construction Cost

The construction cost in this study is composed of the items of expenditure as illustrated below:



The followings are explanation for items of expenditure for construction works.

(1) Expenditure for consultant (2)

The expenditure for consultant (2) includes detailed investigation of each bridge, preparation of detail designs and supervision during the entire period for improvement work. The detail designs include also arrangement for construction, i.e. cost estimation, contract award and specifications.

(2) General overhead charge (7)

The general overhead charge (7) is required to assure the contractor's normal operation, and consists of directors' salaries, employee payroll, office supplies, traveling and building rents and other costs expenses. It is generally expressed as a percentage to the direct cost for construction (6) . For the purpose of the present cost estimation, the overhead percentage was empirically assumed to be 13% for all the proposed construction works.

(3) Materials cost (11)

The materials Cost (11) includes the costs for all the structural materials such as steel plates and angle steels except the materials for the temporary installations.

(4) Auxiliary materials cost (12)

The auxiliary materials cost (12) includes the costs for all the consumed materials not involved in "Materials Cost" (11) such electrodes and gas.

(5) Manufacturing cost (13)

The manufacturing cost (13) includes the costs for fabrication of structural members, temporary assembly, shop painting and secondary labors and factory overhead charges, etc.

(6) Cost for direct construction at site (14)

This cost (14) includes the cost for local transport and erection of bridge structural members, field painting, equipments, track work, scaffolding, construction plant, etc.

(7) Domestic transport charge (15)

The domestic transport charge (15) means the cost transport of the structural members from the factory or port to the railway station nearest to the site and the cost for loading and unloading them.

(8) Cost for temporary installations (17)

This cost (17) includes the costs for transport of construction plant and equipment, safety facilities, site offices, laborers' sleeping quarters, temporary bridges, surveying, etc. The cost is expressed as a percentage to the cost for direct construction at site (14) except where special temporary installations are necessary.

For the present purposes, the percentage was empirically assumed as follows:

For replacement works	10% of the cost for direct construction at site (14)
For strengthening works	15% of the cost for direct construction at site (14)

(9) Site overhead charge (18)

The site overhead charge (18) includes the costs for labor management, heating and lighting, office supplies, traveling expenses, communication charges and miscellaneous costs. The overhead charge is usually expressed as a percentage to the total cost of (14) (15) and (17) for works. In the present case, the percentage was assumed as 12.5% of their cost.

2. Classification of Currency

The classification of domestic currency and foreign currency used in the present cost estimation is as shown in Table-1.

Table - 1 Classification of Domestic Currency and Foreign Currency

Items		Domestic Currency	Foreign Currency
Strengthening and Repairing works	Cost for Materials		○
	Cost For Manufacture	○	
	Cost for Temporary Installation	○	
	Machine to be Hired		○
	Labors Cost	○	
	Tool to be Hired	○	○
Replacement works	Cost for Materials		○
	Cost for Manufacture		○
	Cost for Construction at Site	○	
Expenses for detail design and supervision			○

3. Unit Prices

The unit prices for major cost items used in the cost estimation are as showin in Table-2.

4. Data for Overhead Charges In JAPAN

The overhead charges used for the cost estimation are based on the data shown in Table-3, which are generally applied to the bridge construction works in Japan.

Table - 2 Unit Prices as of 1976 year

Item		Kind	Unit	Unit Cost (Baht)	Remarks
Labors costs		Construction leader	man/day	200	These costs include food expenses, compensation for a monthly income, etc.
		Skilled laborer	〃	60	
		Construction worker	〃	100	
		Black Smith	〃	150	
		Painter	〃	80	
		Operater of machine	〃	200	
		Guard man	〃	50	
		Day laborer	〃	40	
		Local foreman	〃	200	
		Local engineer	〃	300	
Cost of machine instal-lation	Con-struc-tion ma-chine	Construct girder	ton/day	17	Commercial cost, repairing cost
		Winch	set/day	31	
		Air compresser	〃	168	
		Generator	〃	170	
		Pulley (300ϕ x one pulley)	〃	2	
		Pulley (300ϕ x two pulley)	〃	3	Life of the machine (5 or 7 years)
	Spe-cial tools	Impact wrench	〃	15	
		Hydraulic wrench	〃	93	
		Torque wrench	〃	7	
		Calibrater	〃	37	
		Journal jack	〃	24	
		Pick hammer	〃	4	
		Drop hammer	〃	2	
		Drift pin	100 pcs.	3	
		Grinder	set/day	5	
		Drill	〃	12	
		Rivetting hammer	〃	7	
		Bucker	〃	5	
Cost of mate-rials	Fuel	Heavy oil (1)	Liter	3	
		Gasoline (2)		4	
		Oil and gas, etc.	Set		((1) + (2)) x 25%
	Others	Hard timber	m^3	3000	Domestic price
		General timber	〃	2000	
		Staging for construction	〃	65	Average cost
		Painting	m^2	14	Field painting, 2 coat
		Nonshrinkage mortar	m^3	1530	
Cost of steel materials		Steel plate (length 6m)	Ton	7500	Import: including business margin (6%) transportation cost tax. etc. (25.52%) for C.I.F.
		Shape steel (〃)	〃	8000	
		Steel Rod	〃	11000	
		High strength bolt	〃	23130	
		Rivet	〃	13590	
Cost of fabrication			〃	10000	Fabricated by local bridge shop

Table - 3 Examples of overhead Charges for Cost Estimation of Bridge Construction Work in Japan

1. Rates of General Overhead Charge for Total Construction Cost

Total Construction Cost (in thousand Yen)	Rate (%)
Under 1,000	15.0
1,000 ∿ 2,000	14.6
2,000 ∿ 3,000	14.4
3,000 ∿ 4,000	14.2
4,000 ∿ 5,000	14.1
5,000 ∿ 6,000	14.0
6,000 ∿ 7,000	13.9
7,000 ∿ 8,000	13.8
8,000 ∿ 9,000	13.8
9,000 ∿ 10,000	13.7
10,000 ∿ 20,000	13.3
20,000 ∿ 30,000	13.1
30,000 ∿ 40,000	12.9
40,000 ∿ 50,000	12.8
50,000 ∿ 60,000	12.7
60,000 ∿ 70,000	12.6
70,000 ∿ 80,000	12.6
80,000 ∿ 90,000	12.5
90,000 ∿ 100,000	12.4
100,000 ∿ 200,000	12.0
200,000 ∿ 300,000	11.8
300,000 ∿ 400,000	11.6
400,000 ∿ 500,000	11.5
500,000 ∿ 600,000	11.4
600,000 ∿ 700,000	11.3
700,000 ∿ 800,000	11.2
800,000 ∿ 900,000	11.2
Over 900,000	11.0

2. Rates of Site Overhead Charge for Net Construction Cost

Net Construction Cost (in thousand Yen)	Rate (%)
Under 5,000	15.9
5,000 ∿ 6,000	15.2
6,000 ∿ 7,000	14.7
7,000 ∿ 8,000	14.3
8,000 ∿ 9,000	13.9
9,000 ∿ 10,000	13.6
10,000 ∿ 20,000	11.6
20,000 ∿ 30,000	10.6
30,000 ∿ 40,000	10.0
40,000 ∿ 50,000	9.5
50,000 ∿ 60,000	9.1
60,000 ∿ 70,000	8.8
70,000 ∿ 80,000	8.5
80,000 ∿ 90,000	8.3
90,000 ∿ 100,000	8.1
100,000 ∿ 200,000	8.1
200,000 ∿ 300,000	8.1
300,000 ∿ 400,000	8.1
Over 400,000	8.1

NOTE: The rates for overhead charges shown in the above tables should be modified according to the conditions of construction.

APPENDIX IV

EXPERIMENT ON HIGH STRENGTH BOLT JOINT OF OLD PLATE

EXPERIMENT ON HIGH-STRENGTH BOLT JOINT OF OLD PLATES

The best quality of surfaces of plates to be in contact in the high-strength bolt connection is obtained by sand-or shot-blasting. It is applicable in assembly of a new bridge but it is often difficult or impossible in strengthening or repair work of an existing bridge.

If old paint or rust between plates remains or incompletely removed, the joint will slip prematurely.

The present experiment was conducted to show how the friction between the plates varied according to the extent of removal of the old paint and rust by flame cleaning. However, it presents only an example under a particular condition in Japan. The results will differ according to the kind and age of the paint between the plates, the technique of flame cleaning and the original treatment of the contact surfaces.

Therefore, it is important to conduct experiments on the specimens which are taken from an old dismantled bridge of similar conditions to the bridge to which high-strength bolts are intended to be applied in repair or strengthening work and which are processed in the same cleaning method and to the same extent as in the actual work. Thus, according to the results of the experiments the allowable strength of high-strength bolt connection should be reduced or the number of bolts should be increased.

1. Specimens

Specimens were taken from web splice portions and intermediate stiffeners of old plate girder bridges of about 60 years of age, as shown in Fig. 1. The shapes of the specimens and the position of gauges to measure the slippage are shown in Fig. 2. The dimensions of plates and the total bolt clamping force of the specimens were so proportioned that the plates may not attain the yield point before slip takes place between the plates in loading.

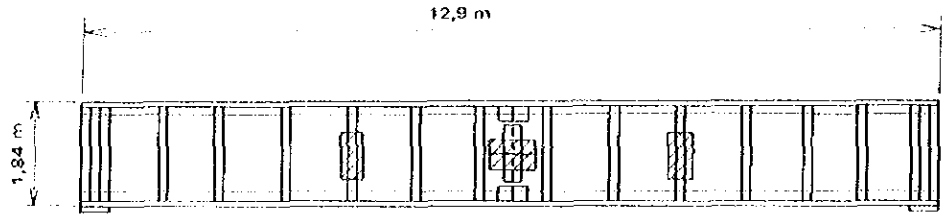
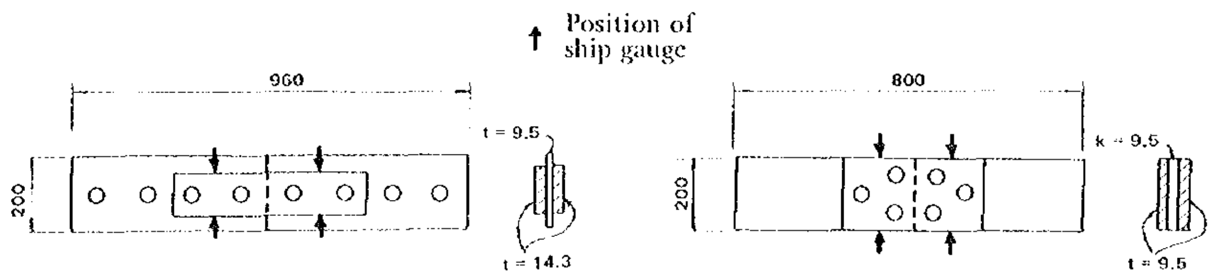


Fig. 1 Positions of Specimens



Bolt ; M22, F10T
Specimen from intermediate stiffener

Bolt ; M22, F10T
Specimen from web splice

Fig. 2 Shape of Specimen and Position of Slip Measurement

2. Condition of Contact Surfaces

The condition of cleaning was varied to four cases as follows; Case 1, no cleaning, the paint not being removed at all, Case 4, complete cleaning, the paint being completely removed, Case 2 and Case 3, being two intermediate conditions between Case 1 and Case 4.

In addition the practice for a new bridge to be assembled with rivets was tried, being designated as Case 5, namely new red lead paint was applied after complete cleaning.

3. Test Procedure

One of the relations between the applied load and the amount of slip in the connections is shown in Fig. 3.

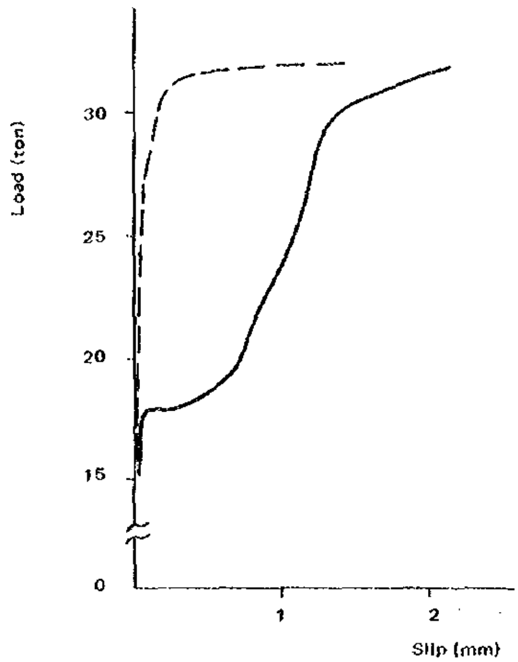


Fig. 3 An Example of Relation between Load and Slip

4. Result and Discussion

The result of experiment is summarized in Fig. 4. Case 5 is the worst and such a method as usually applied to rivet joints should not be adopted to high-strength bolt joints.

Case 1 presents a value of about 0.2, the worst among the tests on the old members. But it is better than Case 5, and this seems to be because old paint is less slippery than new one.

It is interesting that Cases 2, 3 and 4 yielded about identical frictional coefficients, about 0.3. The reason why even Case 4 (complete removal of old paint) showed as low a value as 0.3 seems that because the plates was not originally subject to sand blasting, mill scale remained, even after flame cleaning (in the case of mill scale on, 0.3 is quite probable.).

The allowable strengths of high-strength bolt connection presented in the current specifications are based on the assumption that at least 0.4 is ensured as a frictional coefficient.

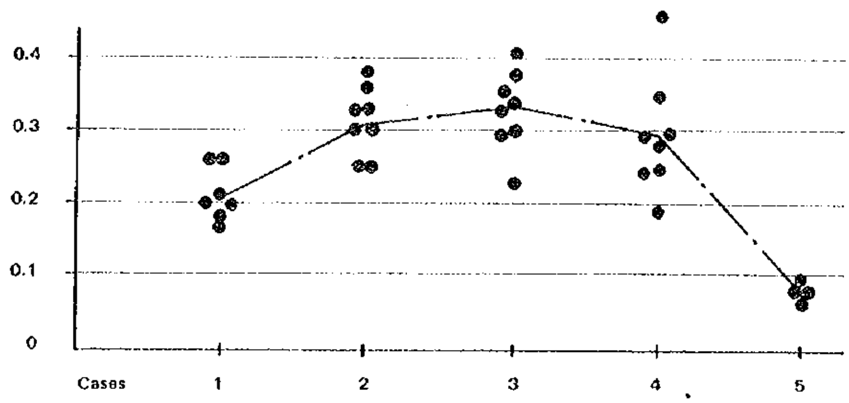


Fig. 4 Summary of Coefficients of Friction

According to the results of the present experiment the allowable strength should be reduced to 0.75 of the normal allowable strength, even the contact surface is subject to thorough flame cleaning.

Anyway the allowable strength for repair and strengthening of bridges in RSR should be determined based on its own experiments.

APPENDIX V

RELATION BETWEEN BRIDGE STRENGTH AND TRAIN SPEED RESTRICTION IN JNR

Relation between Bridge Strength and Train Speed Restriction in J.N.R.

It is generally known that a train at a lower speed has a less impact effect on bridges than a train at a higher speed.

Therefore, in case a train is heavier than the one assumed for the design of a bridge, or in case the sectional areas of members of a bridge have been reduced due to corrosion, a train may be allowed to pass the bridge if the train speed is reduced accordingly.

The allowable stresses for bridge members may somewhat be increased (for instance, 1.25 times in J.N.R.), if such trains pass temporarily or during a limited length of period, and the strength of bridge is periodically checked.

In J.N.R. the speed restriction is determined as shown in the following table, and the derivation of values in the table is explained next.

Span in meters / Capacity	Maximum train speed (km/hr)											
	Steam Locomotive				Electric Locomotive Diesel Locomotive				Electric Car Diesel Car			
	<10	10 - 20	20 - 30	>30	<10	10 - 20	20 - 30	>30	<10	10 - 20	20 - 30	>30
90				115								
88				110								
86				100					125			
84			110	95					120			125
82			105	90					115	125	125	120
80		115	100	85	120			120	105	115	120	115
78	115	106	90	80	110	120	120	110	100	110	110	105
76	110	95	85	70	100	110	110	100	90	100	105	100
74	100	90	75	65	95	105	105	95	85	95	95	90
72	90	80	65	55	85	95	95	85	80	85	85	85
70	85	75	60	50	80	85	85	75	70	80	80	75
68	75	65	55	40	70	75	75	65	65	70	70	70
66	65	60	50	35	60	65	65	55	55	60	65	60
64	60	50	45	30	55	60	55	50	50	55	55	50
62	50	45	35	25	45	50	50	40	45	50	50	45
60	40	35	25	20	35	45	40	30	35	40	40	40

Note: For stringers L is the panel length, and for floor beams L is the sum of the lengths of the adjacent stringers.

(1) I_o, The total effect of impact

There are many effects constituting the total impact acting to a bridge. But it can be simplified to Equation (1).

$$I_o = I_c + K_a \cdot \alpha \quad \cdots\cdots (1)$$

where I_c; Effect of vibration to which a rolling stock is subject before it enters the bridge.

$K_a \cdot \alpha$; Effect of acceleration of deflection of bridge due to loading of rolling stock.

For a steam locomotive another term is added for hammer blow action of wheels, but now the case of steam locomotives is not considered.

(2) I_c, Effect of rolling stock vibrating before entrance to a bridge

It is the effect of vibration of a rolling stock to which the rolling stock is already subject due to irregularity of tracks, etc., before it enters the bridge. The effect is approximately expressed by Equation (2).

$$I_c = \frac{3.6}{L + 30} \quad \cdots\cdots (2)$$

where L; Span length of bridge in meters

(3) $K_a \cdot \alpha$, Effect of acceleration of deflection of the bridge due to loading of rolling stock.

As a rolling stock changes its position on the bridge at a certain speed, it changes the deflection of the bridge forcibly, thus, producing a dynamic effect on the bridge.

K_a is a coefficient which varies according to the kinds of rolling stocks, for instance, K_a = 2.5 to 3 for diesel locomotive, and K_a = 3.5 to 4 for electric car and diesel car.

α is a parameter with regard to speed, and simplified as the following formula.

$$\alpha = \frac{V}{6.4\, n\, L} \quad \cdots\cdots (3)$$

where L; Span length in meters,

V; Speed of rolling stock in kilometers per hour

n; Natural frequency in Hertz of bridge together with rolling stocks. It is expressed approximately by the following formula.

$$n = \sqrt{\frac{31.5}{d + D}}$$

where d; Deflection at the span center in centi-meter due to dead load.

D; Deflection at the span center in centi-meter due to rolling stocks

(4) Relation between strength of bridge and impact of rolling stock to be permitted.

The strength ratio of bridge is expressed as follows;

$$\beta = \frac{\text{Allowable capacity of bridge for rolling stock}}{\text{Actual rolling stock to be loaded on the bridge}} \quad \cdots\cdots (6)$$

$$\text{or} \quad \frac{\text{KS-Value of the bridge}}{\text{KS-Value of the rolling stock}} \quad \cdots\cdots (7)$$

$$\text{or} \quad \frac{(\text{Allowable stress in design}) - (\text{Stress due to dead load})}{(\text{Stress due to rolling stock}) + (\text{Stress due to impact})} \quad \cdots\cdots (8)$$

where stresses are calculated on the basis of the remaining sectional area of a member reduced by corrosion.

β is expressed in stress symbols as follows:

$$\beta = \frac{\sigma_a - \sigma_d/\gamma}{\sigma_\ell(1+I)/\gamma} = \frac{\sigma_a \cdot \gamma - \sigma_d}{\sigma_\ell\ (1+I)} \quad \cdots\cdots \quad (9)$$

where σ_a; Allowable stress in original design

σ_d; Stress due to dead load in original member section

σ_ℓ; Stress due to rolling stock in original member section

$$\gamma = \frac{\text{Remaining sectional area}}{\text{Original sectional area}}$$

I; Impact coefficient used for design

For the sake of safety of bridge, the train speed must be reduced so that the impact value (I_r) is small enough to make the value of Equation (9) less than 1.0. Then,

$$1.0 = \frac{\sigma_A \cdot \gamma - \sigma_d}{\sigma_\ell\ (1+I_r)} \quad \cdots\cdots \quad (10)$$

Hence,

$$\sigma_A = \frac{\sigma_\ell(1+I_r)+\sigma_d}{\gamma} \quad \cdots\cdots \quad (11)$$

where σ_A: Allowable stress for maintenance

From Equation (11)

$$I_r = \frac{\sigma_A \cdot \gamma}{\sigma_\ell} - \frac{\sigma_d}{\sigma_\ell} - 1 \quad \cdots\cdots \quad (12)$$

In J.N.R. the following allowable stresses are adopted;

$$\left.\begin{array}{l} \sigma_a = 1{,}200\text{kg/cm}^2 \text{ for original design} \\ \sigma_A = \sigma_a \times 1.25 = 1{,}500\text{kg/cm}^2 \text{ for maintenance} \end{array}\right\} \cdots\cdots \quad (13)$$

From Equations (9), (12) and (13)

$$I_r = \sigma\ 1.25\beta\ (1+I) + 0.25\ \sigma_d/\sigma_\ell - 1 \quad \cdots\cdots \quad (14)$$

(5) Relation between strength ratio of bridge and speed restriction of train

By assuming that I_o in Equation (1) and I_r in Equation (14) are equal, the relation between bridge strength and speed allowed for train can be obtained. Practically it is obtained by using charts. For combination of a particular bridge and a particular rolling stock, a relation is drawn as shown in the following figure. Then the relation between β and V can be obtained graphically. In the table shown in the first page, the last figure of each speed is rounded to 0 or 5.