## 7.4 Evaluation of the Existing Bridges Based on the Load Bearing Capacity

1) Load Bearing Capacity of the Main Girder

The load bearing capacity and the degree of safety under the test load are calculated on the three representative RC bridges No. 1, No. 2 and No. 3 and two PC bridges No. 6 and No. 9, for a total of 5 bridges using the present AASHTO HS20-44 live load as described in 7.4.1. For the RC bridges the load on the main girder considers the load distribution calculation by the grid calculation method and the base factor f = 1.0 and the bending rupture factor ($\gamma$) is determined.

The new Omani Uniform Load and Concentrated Load which uses a live load of AASHTO HS20-44 x 2, the load bearing capacity and safety factor is calculated to determine the load bearing capacity of the main girders.

On the other hand, the live load system of Omani Design Standard of 60 ton truck x 2 is the largest live load, the actual load bearing capacity is calculated, and the result compared with the allowable load bearing capacity to determine whether it is within the allowable stress or to what degree it exceeds it.

2) Load Capacity of Decks

The bridge deck is that component of a bridge that the live load is directly in contact with, and is subject to repeated fatigue loads. The safety of the bridge is calculated from its condition, and the design of the deck is based on the rear wheel load of truck loads.

For the RC and PC bridges, load testing is performed with a 7.0 ton rear wheel load, and the heaviest AASHTO 7.26 (1+i) ton design standard from which the allowable load capacity is compared for the slab in order to investigate bridge safety.

The bridge slab is subject to repeated loads and fatigue loads as stated previously, and the design standards used in Japan are used for the allowable values for this study, and the allowable stress for the concrete ($\sigma_{ca}$) will be one-third of the $\sigma_{28}$ for $\sigma_{ca}$ = 71 kg/cm$^2$ or 90 kg/cm$^2$, the allowable stress for reinforcing bar ($\sigma_{sa}$) for the slab is assumed for $\sigma_{sa}$ = 1,400 kg/cm$^2$ at a low value where the normal stress is 1,800 kg/cm$^2$.

3) Substructure Supports

There are cracks in the rigid frame pier of the substructure and so the live loads are calculated in accordance with the AASHTO live load systems and compared with the actual loads.

### 7.4.1 Calculation of the Load Capacity under the Current AASHTO HS20-44 Live Load

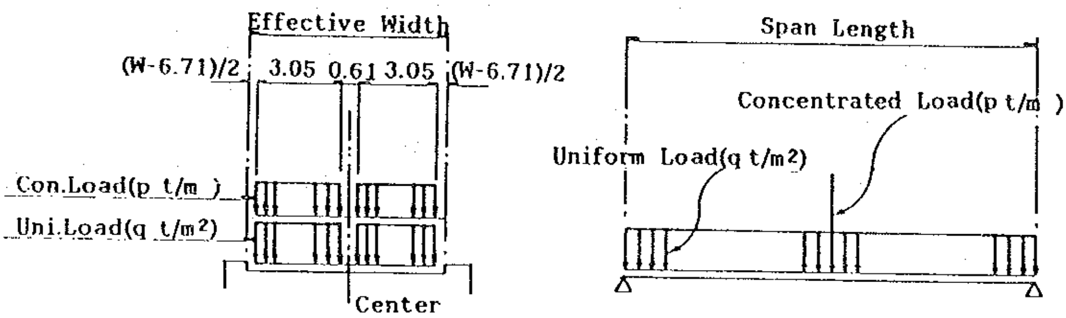
1) The AASHTO Live Load Condition

AASHTO HS20-44 (32 ton)

AASHTO HS20-44 (32 ton) (Standard HS Truck)

a) Analysis for Main Girder and Cross Beam

AASHTO HS 20–44 (32 Ton)

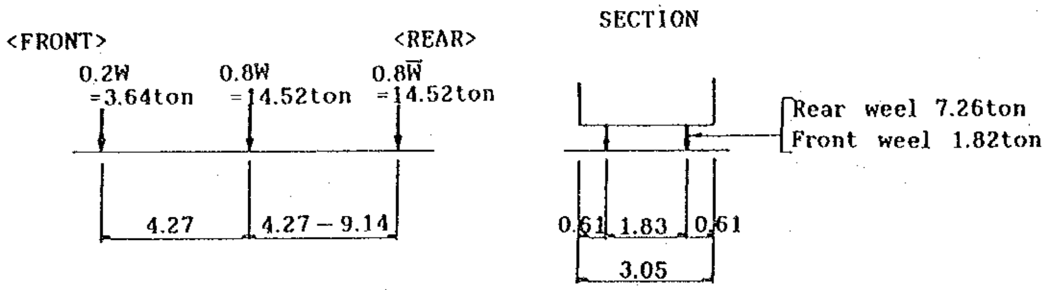



| | | |
|---|---|---|
| Concentrated Load | : | 8.16 ton per 1 Lane |
| | | ( Con. Load 8.16 / 3.05 = 2.68 ( 1 + i ) t/m = p ) |
| Uniform Load | : | 0.96 ton m per 1 Lane |
| | | ( Uni. Load 0.96 / 3.05 = 0.31 ( 1 + i ) t/m$^2$ = q ) |
| Impact Load | : | i = 15 / L + 38 , L = Span Length (m) |

b) Analysis for Bridge Slab

The new Omani Live Load Standard can be obtained by multiplying the AASHTO HS20-44 Live Load Standard by 2 to obtain the live load bending moment.

AASHTO HS 20−44 (32 TON)(STANDARD HS TRUCK)




W = 40 000 LSB =18.150ton

2) Results of Calculation of Bending Moment for Bridges by the AASHTO HS20-44 Live Load

**Table 7.20 Results of Bending Moment by AASHTO HS-20 (RC, PC)**

| Bridge No. | AASHTO HS 20-44 | Bending Moment (t • m) | | | Remarks |
|---|---|---|---|---|---|
| | | Dead Load | Live Load | Total | |
| RC 1 | Girder G1 | 81.6 | 29.3 | 110.9 | |
| | G2 | 82.8 | 40.9 | 123.7 | |
| RC 2 (3.4) | Girder G1 | 104.8 | 35.9 | 140.7 | |
| | G2 | 75.8 | 34.6 | 110.4 | |
| RC 5 (8) | Girder G1 | 104.2 | 35.7 | 139.9 | |
| | G2 | 75.4 | 34.5 | 109.9 | |
| PC (6) | Girder G1 | 313.7 | 99.0 | 412.7 | |
| | G2 | 330.8 | 91.0 | 421.8 | |
| | G3 | 329.4 | 87.0 | 416.4 | |
| PC 9 (7) | Girder G1 | 83.4 | 23.6 | 107.0 | |
| | G2 | 87.7 | 27.5 | 115.2 | |
| | G3 | 84.0 | 31.2 | 115.2 | |
| | G4 | 81.8 | 32.9 | 114.7 | |

Calculation of Stress and Deflection in the RC Bridges by the AASHTO HS 20-44 Live Load Criteria.

**Table 7.21 Results of Strength and Deflection for Bridge No. 1**

| | | | | Dead Load | (HS20) |
|---|---|---|---|---|---|
| G1 | 1/4 | Bending Moment | ton.m | 61.57 | 17.15 |
| | | Delta | mm | 2.75 | 0.86 |
| | | σc | $kg/cm^2$ | 18.2 | 5.1 |
| | | σs | $kg/cm^2$ | 763 | 212 |
| | CL | Bending Moment | ton.m | 81.42 | 29.27 |
| | | Delta | mm | 3.86 | 1.24 |
| | | σc | $kg/cm^2$ | 24.0 | 8.6 |
| | | σs | $kg/cm^2$ | 1009 | 363 |
| | 3/4 | Bending Moment | ton.m | 61.59 | 17.15 |
| | | Delta | mm | 2.74 | 0.86 |
| | | σc | $kg/cm^2$ | 18.2 | 5.1 |
| | | σs | $kg/cm^2$ | 763 | 212 |
| G2 | 1/4 | Bending Moment | ton.m | 57.45 | 25.91 |
| | | Delta | mm | 2.52 | 1.16 |
| | | σc | $kg/cm^2$ | 14.9 | 6.7 |
| | | σs | $kg/cm^2$ | 708 | 319 |
| | CL | Bending Moment | ton.m | 82.98 | 40.86 |
| | | Delta | mm | 3.56 | 1.66 |
| | | σc | $kg/cm^2$ | 21.6 | 10.6 |
| | | σs | $kg/cm^2$ | 1022 | 503 |
| | 3/4 | Bending Moment | ton.m | 57.43 | 25.91 |
| | | Delta | mm | 2.51 | 1.16 |
| | | σc | $kg/cm^2$ | 14.9 | 6.7 |
| | | σs | $kg/cm^2$ | 708 | 319 |
| G3 | 1/4 | Bending Moment | ton.m | 57.45 | 25.91 |
| | | Delta | mm | 2.52 | 1.16 |
| | | σc | $kg/cm^2$ | 14.9 | 6.7 |
| | | σs | $kg/cm^2$ | 708 | 319 |
| | CL | Bending Moment | ton.m | 82.95 | 40.86 |
| | | Delta | mm | 3.56 | 1.66 |
| | | σc | $kg/cm^2$ | 21.6 | 10.6 |
| | | σs | $kg/cm^2$ | 1022 | 503 |
| | 3/4 | Bending Moment | ton.m | 57.43 | 25.91 |
| | | Delta | mm | 2.51 | 1.16 |
| | | σc | $kg/cm^2$ | 14.9 | 6.7 |
| | | σs | $kg/cm^2$ | 708 | 319 |
| G4 | 1/4 | Bending Moment | ton.m | 61.57 | 14.15 |
| | | Delta | mm | 2.75 | 0.86 |
| | | σc | $kg/cm^2$ | 18.2 | 4.2 |
| | | σs | $kg/cm^2$ | 763 | 175 |
| | CL | Bending Moment | ton.m | 81.42 | 29.27 |
| | | Delta | mm | 3.86 | 1.24 |
| | | σc | $kg/cm^2$ | 24.0 | 8.6 |
| | | σs | $kg/cm^2$ | 1009 | 363 |
| | 3/4 | Bending Moment | ton.m | 61.59 | 17.15 |
| | | Delta | mm | 2.74 | 0.86 |
| | | σc | $kg/cm^2$ | 18.2 | 5.1 |
| | | σs | $kg/cm^2$ | 763 | 212 |

**Table 7.22 Results of Strength and Deflection for Bridge No. 2**

| | | | | Dead Load | (HS20) |
|---|---|---|---|---|---|
| G1 | 1/4 | Bending Moment | ton.m | 79.04 | 20.91 |
| | | Delta | mm | 4.82 | 1.46 |
| | | σc | $kg/cm^2$ | 39.6 | 10.5 |
| | | σs | $kg/cm^2$ | 996 | 263 |
| | CL | Bending Moment | ton.m | 104.84 | 35.87 |
| | | Delta | mm | 6.79 | 2.09 |
| | | σc | $kg/cm^2$ | 52.5 | 18.0 |
| | | σs | $kg/cm^2$ | 1321 | 452 |
| | 3/4 | Bending Moment | ton.m | 79.04 | 20.91 |
| | | Delta | mm | 4.82 | 1.46 |
| | | σc | $kg/cm^2$ | 39.6 | 10.5 |
| | | σs | $kg/cm^2$ | 996 | 263 |
| G2 | 1/4 | Bending Moment | ton.m | 54.49 | 22.36 |
| | | Delta | mm | 4.66 | 1.99 |
| | | σc | $kg/cm^2$ | 44.0 | 18.0 |
| | | σs | $kg/cm^2$ | 746 | 306 |
| | CL | Bending Moment | ton.m | 75.77 | 34.56 |
| | | Delta | mm | 6.57 | 2.84 |
| | | σc | $kg/cm^2$ | 61.1 | 27.9 |
| | | σs | $kg/cm^2$ | 1037 | 473 |
| | 3/4 | Bending Moment | ton.m | 54.49 | 22.36 |
| | | Delta | mm | 4.66 | 1.99 |
| | | σc | $kg/cm^2$ | 44.0 | 18.0 |
| | | σs | $kg/cm^2$ | 746 | 306 |
| G3 | 1/4 | Bending Moment | ton.m | 54.49 | 22.36 |
| | | Delta | mm | 4.66 | 1.99 |
| | | σc | $kg/cm^2$ | 44.0 | 18.0 |
| | | σs | $kg/cm^2$ | 746 | 306 |
| | CL | Bending Moment | ton.m | 75.77 | 34.56 |
| | | Delta | mm | 6.57 | 2.84 |
| | | σc | $kg/cm^2$ | 61.1 | 27.9 |
| | | σs | $kg/cm^2$ | 1037 | 473 |
| | 3/4 | Bending Moment | ton.m | 54.49 | 22.36 |
| | | Delta | mm | 4.66 | 1.99 |
| | | σc | $kg/cm^2$ | 44.0 | 18.0 |
| | | σs | $kg/cm^2$ | 746 | 306 |
| G4 | 1/4 | Bending Moment | ton.m | 79.05 | 20.91 |
| | | Delta | mm | 4.83 | 1.46 |
| | | σc | $kg/cm^2$ | 39.6 | 10.5 |
| | | σs | $kg/cm^2$ | 996 | 263 |
| | CL | Bending Moment | ton.m | 104.84 | 35.87 |
| | | Delta | mm | 6.79 | 2.09 |
| | | σc | $kg/cm^2$ | 52.5 | 18.0 |
| | | σs | $kg/cm^2$ | 1321 | 452 |
| | 3/4 | Bending Moment | ton.m | 79.05 | 20.91 |
| | | Delta | mm | 4.83 | 1.46 |
| | | σc | $kg/cm^2$ | 39.6 | 10.5 |
| | | σs | $kg/cm^2$ | 996 | 263 |

**Table 7.23 Results of Strength and Deflection for Bridge No. 5, 8**

| | | | | Dead Load | (HS20) |
|---|---|---|---|---|---|
| G1 | 1/4 | Bending Moment | ton.m | 78.37 | 20.79 |
| | | Delta | mm | 4.80 | 1.44 |
| | | σc | $kg/cm^2$ | 41.6 | 11.0 |
| | | σs | $kg/cm^2$ | 1234 | 327 |
| | CL | Bending Moment | ton.m | 104.07 | 35.66 |
| | | Delta | mm | 6.76 | 2.06 |
| | | σc | $kg/cm^2$ | 55.3 | 18.9 |
| | | σs | $kg/cm^2$ | 1639 | 562 |
| | 3/4 | Bending Moment | ton.m | 78.38 | 20.79 |
| | | Delta | mm | 4.78 | 1.44 |
| | | σc | $kg/cm^2$ | 41.6 | 11.0 |
| | | σs | $kg/cm^2$ | 1234 | 327 |
| G2 | 1/4 | Bending Moment | ton.m | 54.35 | 22.27 |
| | | Delta | mm | 4.65 | 1.96 |
| | | σc | $kg/cm^2$ | 46.9 | 19.2 |
| | | σs | $kg/cm^2$ | 924 | 379 |
| | CL | Bending Moment | ton.m | 75.46 | 34.47 |
| | | Delta | mm | 6.55 | 2.80 |
| | | σc | $kg/cm^2$ | 65.1 | 29.7 |
| | | σs | $kg/cm^2$ | 1283 | 586 |
| | 3/4 | Bending Moment | ton.m | 54.35 | 22.27 |
| | | Delta | mm | 4.63 | 1.96 |
| | | σc | $kg/cm^2$ | 46.9 | 19.2 |
| | | σs | $kg/cm^2$ | 924 | 379 |
| G3 | 1/4 | Bending Moment | ton.m | 54.35 | 22.27 |
| | | Delta | mm | 4.65 | 1.96 |
| | | σc | $kg/cm^2$ | 46.9 | 19.2 |
| | | σs | $kg/cm^2$ | 924 | 379 |
| | CL | Bending Moment | ton.m | 75.46 | 34.47 |
| | | Delta | mm | 6.55 | 2.80 |
| | | σc | $kg/cm^2$ | 65.1 | 29.7 |
| | | σs | $kg/cm^2$ | 1283 | 586 |
| | 3/4 | Bending Moment | ton.m | 54.35 | 22.27 |
| | | Delta | mm | 4.63 | 1.96 |
| | | σc | $kg/cm^2$ | 46.9 | 19.2 |
| | | σs | $kg/cm^2$ | 924 | 379 |
| G4 | 1/4 | Bending Moment | ton.m | 78.37 | 20.79 |
| | | Delta | mm | 4.80 | 1.44 |
| | | σc | $kg/cm^2$ | 41.6 | 11.0 |
| | | σs | $kg/cm^2$ | 1234 | 327 |
| | CL | Bending Moment | ton.m | 104.07 | 35.66 |
| | | Delta | mm | 6.76 | 2.06 |
| | | σc | $kg/cm^2$ | 55.3 | 18.9 |
| | | σs | $kg/cm^2$ | 1639 | 562 |
| | 3/4 | Bending Moment | ton.m | 78.37 | 20.79 |
| | | Delta | mm | 4.78 | 1.44 |
| | | σc | $kg/cm^2$ | 41.6 | 11.0 |
| | | σs | $kg/cm^2$ | 1234 | 327 |

Load Bearing Capacity of Slab for the 4 Bridge Type

The calculation results are shown in the Table.

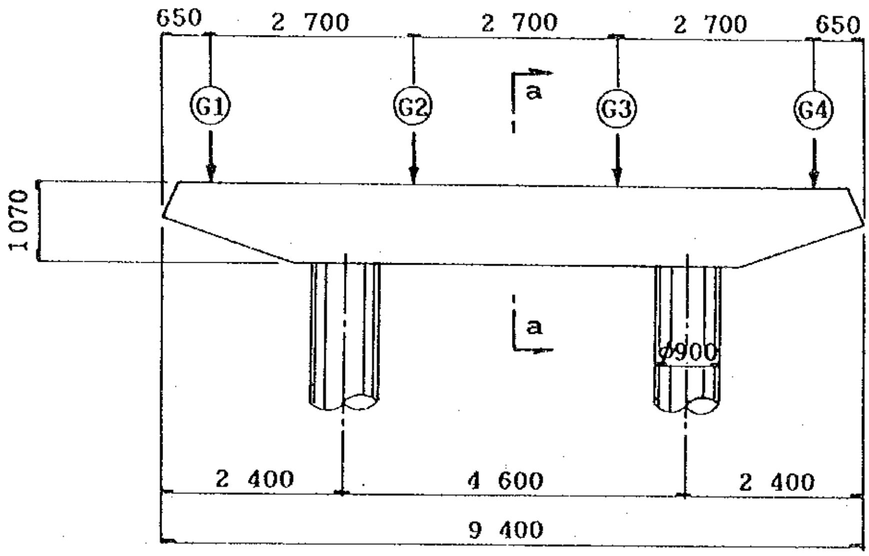
**Table 7.24 Calculation Results of Slab for the Bridges**

| | | | Br. No. 1 | Br. No. 2, 3, 4, 5, 8 | Br. No. 7, 9 | | Br. No. 6 |
|---|---|---|---|---|---|---|---|
| | | | | | *1Cast in Place RC Slab Only | *2Cast in Place+ Precast Slab | |
| Slab Span ℓ (m) | | | 2.4 | 2.26 | 0.8 | 0.8 | 1.9 |
| Impact i | | | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| Slab Thickness t (cm) | | | 17 | 17 | 13 | 18 | 18 |
| Slab Condition | | | continuous | simple | simple | simple | continuous |
| Wd (t/m) | | | 0.54 | 0.54 | 0.44 | 0.565 | 0.565 |
| Md (t/m) | | | 0.311 | 0.345 | 0.035 | 0.045 | 0.204 |
| Mℓ | P20 = 7.26t | | 2.333 | 2.781 | 1.361 | 1.361 | 1.946 |
| | P = 5.39t (i=0) | | 1.731 | 2.063 | 1.009 | 1.009 | 1.443 |
| M=Md+Mℓ | P20 | | 2.64 | 3.13 | 1.40 | 1.41 | 2.15 |
| | P | | 2.04 | 2.41 | 1.04 | 1.05 | 1.65 |
| d' (mm) | | | 38 | 37 | 36 | 30 | |
| d (cm) | | | 13.2 | 13.3 | 9.4 | 15 | 14 |
| As ($cm^2$) | | | ø16ctc 12.5cm | ø14ctc 10cm | ø8ctc 20cm | | ø14ctc 10cm |
| | | | 8-ø16=16.08 | 10-ø14=15.39 | 5-ø8=2.51 | 10-ø10=7.85 | 10-ø14=15.39 |
| $P = As/bd$ | | | 0.0122 | 0.0116 | 0.00267 | 0.00523 | 0.0110 |
| $k = \sqrt{n^2p^2 + 2np} - np$ | | | 0.449 | 0.441 | 0.246 | 0.325 | 0.433 |
| $o = 1 - \frac{1}{3}k$ | | | 0.850 | 0.853 | 0.918 | 0.892 | 0.856 |
| x = kd | | | 5.93 | 5.87 | 2.31 | 4.88 | 6.06 |
| $\frac{M}{bd^2}$ | P20 | | 15.15 | 17.69 | 15.84 | 6.27 | 10.97 |
| | P | | 11.71 | 13.62 | 11.77 | 4.67 | 8.42 |
| *3AASHTO Load | P20=7.26t | σc | 79.4 | 94.1 | 140.3 | 43.3 | 59.2 |
| | (x1.3=9.44t) | σs | 1461 | 1788 | 6463 | 1344 | 1165 |
| *3Assumed Load | P=5.39t | σc | 61.4 | 72.4 | 104.2 | 32.2 | 45.4 |
| | (x1.3=7.0t) | σs | 1129 | 1376 | 4802 | 1001 | 894 |
| Allowable Design Compressive Strength = σca | | | 71 | 90 | 71 | | 71 |
| Allowable Design Tensile Strength = σsa | | | 1400 | | | | |
| Allowable Actual Compressive Strength = σca' | | | — | Br. 2, 3, 4, 5 279/3 = 93 | Br. No. 7 333/3 = 111 | Br. No. 9 211/3 = 70 | 328/3 = 109 |

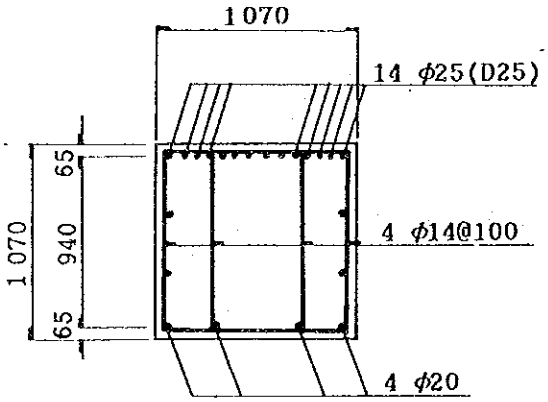
Notes: *1: In case of non-bonding between upper slab (cast in place) and lower slab (precast)
*2: In case of bonding between upper slab (cast in place) and lower slab (precase)
*3: These values of P are based on calculation of AASHTO load by as-built drawing and assumed load of 7 ton equivalent to test truck load.
(x1.3) indicates impact factor.

| Girder No. | Live Load | Dead Load | Total |
|---|---|---|---|
| G 1 | 9.7 | 62.5 | 72.2 |
| G 2 | 18.5 | 45.4 | 63.9 |
| G 3 | 18.5 | 45.4 | 63.9 |
| G 4 | 9.7 | 62.5 | 72.2 |

( Reaction Force on the Pier )




Section




Section a-a

Calculation for Beam

| Rectangular | | | Beam |
|---|---|---|---|
| Section | B | cm | 107.0 |
| | H | cm | 107.0 |
| Force | M | tf·m | 134.593 |
| | N | tf | 0.000 |
| | S | tf | 72.657 |
| Area of Reinforcing | dl | cm | 100.5 |
| | Asl | cm² | 70.938 |
| | | | ( 14-D25 ) |
| | | cm² | 70.938 |
| Strength | σc | kgf/cm² | 79.2 |
| | σs | kgf/cm² | 2142.7 |
| | σs' | kgf/cm² | 0.0 |
| | τ | kgf/cm² | 6.76 |
| Allowable Strength | σca | kgf/cm² | 72.0 |
| | σsa | kgf/cm² | 1800.0 |
| | τa | kgf/cm² | 3.60 |
| Neutral Axis | X | cm | 35.857 |
| Ratio of Young's Modulus n(=Es/Ec) | | | 15.0 |



**Fig. 7.13 Calculation Results for Substructural Beam**

3) Results of Safety Ratio and Load Bearing Capacity of Main Girders for RC Bridges

The results of the safety ratio and load bearing capacity of the main girders in RC Bridges are given in Table 7.25.

**Table 7.25 Results of Safety Ratio of Ultimate Bending Moment and Load Bearing Capacity**

| Bridge No. | Case No. | Girder No. | Md (t.m) | Mℓ (t.m) | $M_{au1}$ = 1.3Md+2.5Mℓ | $M_{au2}$ = 1.7(Md+Mℓ) | Mu (t.m) | f | $\gamma = f \cdot \frac{Mu-1.1Md}{M\ell}$ | $\alpha = \frac{\gamma}{\beta}$ | P = AASHTOxα (32γ)(ton) | $F = \frac{Mu}{Mdu\ max}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | AASHTO HS20 | G1 | 81.6 | 29.3 | 179.3 | 188.5 | 280.7 | 1.0 | 6.52 | 2.61 | 83.5 | 1.49 |
| | | G2 | 82.8 | 40.9 | 209.9 | 210.3 | | | 5.76 | 2.30 | 73.6 | 1.33 |
| | AASHTO 2x(HS20) | G1 | 81.6 | 58.6 | 252.6 | 238.3 | | | 3.26 | 1.30 | 41.6 | 1.11 |
| | | G2 | 82.8 | 81.8 | 312.1 | 279.8 | | | 2.32 | 0.93 | 29.8 | 0.90 |
| 2 (3.4) | AASHTO HS20 | G1 | 104.8 | 35.9 | 226.0 | 239.2 | | | 4.61 | 1.84 | 58.9 | 1.17 |
| | | G2 | 75.8 | 34.6 | 185.0 | 187.7 | | | 5.70 | 2.28 | 73.0 | 1.50 |
| | AASHTO 2x(HS20) | G1 | 104.8 | 71.8 | 315.7 | 300.2 | | | 2.30 | 0.92 | 29.4 | 0.89 |
| | | G2 | 75.8 | 69.2 | 271.5 | 246.5 | | | 2.85 | 1.14 | 36.5 | 1.03 |
| 5 (8) | AASHTO HS20 | G1 | 104.2 | 35.7 | 224.7 | 237.8 | | | 4.65 | 1.86 | 59.5 | 1.18 |
| | | G2 | 75.4 | 34.5 | 184.3 | 186.8 | | | 5.73 | 2.29 | 73.3 | 1.50 |
| | AASHTO 2x(HS20) | G1 | 104.2 | 71.4 | 314.0 | 298.5 | | | 2.33 | 0.93 | 29.8 | 0.89 |
| | | G2 | 75.4 | 69.0 | 270.5 | 245.5 | | | 2.87 | 1.15 | 36.8 | 1.04 |

Notes: $Mu = As \cdot \sigma_{sy} (d - \frac{1}{2} \cdot \frac{As \cdot \sigma_{sy}}{0.85 \cdot \sigma_{28} \cdot b}) = 64.3 \times 4200 \times (117.0 - \frac{1}{2} \times \frac{64.3 \times 4200}{0.85 \times 270 \times 45}) \times 10^{-5} = 280.7$ t.m, $As_{min}$ = 8 - ø32 = 64.3 cm

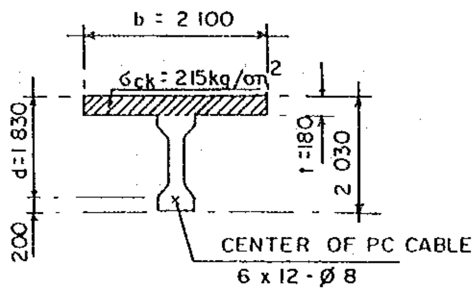
$\beta_{max} = 2.5$

f value = 1.0 (Grid frame work Analysis)

4) Results of Calculation of Load Bearing Capacity of Main Girders of PC Bridges

The load bearing capacity of main girders of PC Bridges have been calculated for the ultimate bending safety ratio and given in Table 7.26 and Table 7.27.

**Table 7.26 Safety Ratio of Load Bearing Capacity for Bridge No. 6 (PC Bridge)**




| | | (tm) Md | (tm) Mℓ | (tm) Mn1 = 1.3Md+2.5Mℓ | (tm) Mn2 = 1.7(Md+Mℓ) | (tm) Mu | F = Mu/Mn |
|---|---|---|---|---|---|---|---|
| AASHTO HS20 | G1 | 313.7 | 99.0 | 655.3 | 701.6 | 890.7 | 1.270 |
| | G2 | 330.8 | 91.0 | 657.5 | 717.1 | | 1.242 |
| | G3 | 329.4 | 87.0 | 645.7 | 707.9 | | 1.258 |
| AASHTO 2x(HS20) | G1 | 313.7 | 198.0 | 902.8 | 869.9 | | 0.987 |
| | G2 | 330.8 | 182.0 | 885.0 | 871.8 | | 1.006 |
| | G3 | 329.4 | 174.0 | 863.2 | 855.8 | | 1.032 |

- $Ap(0.93\,\sigma_{pu}) = 0.85\sigma_{ck} \bullet 0.8x \bullet b,$

$$x = 1.368 \times \frac{\sigma_{pu} \bullet Ap}{\sigma_{ck} \bullet b} = 1.368 \times \frac{15000x36.2}{215x210} = 16.45cm < t=18cm$$

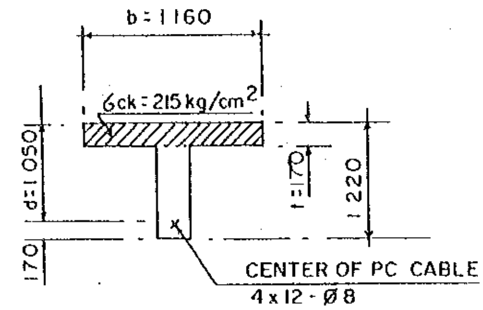
- $$\varepsilon_p = \frac{d-x}{x}\varepsilon_{cu} + \varepsilon_{pe} = \frac{d-x}{x}\varepsilon_{cu} + \frac{\sigma_{pe}}{E_p} = \frac{183-16.45}{16.45} \times 0.0035 + \frac{7875}{20x10^6} = 0.0358 > 0.015$$

- $$Mu = 0.93\,\sigma_{pu} \bullet Ap\left(d - \frac{1}{2} \bullet \frac{\sigma_{pu} \bullet A_p}{0.85\sigma_{ck} \bullet b}\right) = 0.93\,\sigma_{pu} \bullet Ap\left(d - 0.55 \bullet \frac{\sigma_{pu} \bullet A_p}{\sigma_{ck} \bullet b}\right)$$

$$= 0.93 \times 15000 \times 36.2 \times \left(183 - 0.55 \times \frac{15000x36.2}{215x210}\right) \times 10^{-5}$$

$$= 890.7 \text{ tm}$$

**Table 7.27 Safety Ratio of Load Bearing Capacity for Bridge No. 7. 9 (PC Bridge)**




| | | (tm) Md | (tm) Mℓ | (tm) Mn1 = 1.3Md+2.5Mℓ | (tm) Mn2 = 1.7(Md+Mℓ) | (tm) Mu | $F = \frac{Mu}{Mn}$ |
|---|---|---|---|---|---|---|---|
| AASHTO HS20 | G1 | 83.4 | 23.6 | 167.4 | 181.9 | 326.2 | 1.793 |
| | G2 | 87.7 | 27.5 | 182.8 | 195.8 | | 1.666 |
| | G3 | 84.0 | 31.2 | 187.2 | 195.8 | | 1.666 |
| | G4 | 81.8 | 32.9 | 188.6 | 195.0 | | 1.673 |
| AASHTO 2x(HS20) | G1 | 83.4 | 47.2 | 226.4 | 222.0 | | 1.441 |
| | G2 | 87.7 | 55.0 | 251.5 | 242.6 | | 1.297 |
| | G3 | 84.0 | 62.4 | 265.2 | 248.9 | | 1.230 |
| | G4 | 81.8 | 65.8 | 270.8 | 250.9 | | 1.205 |

- $Ap(0.93\,\sigma_{pu}) = 0.85\sigma_{ck} \bullet 0.8x \bullet b,$

  $x = 1.368 \times \frac{\sigma_{pu} \bullet Ap}{\sigma_{ck} \bullet b} = 1.368 \times \frac{15000 \times 24.1}{215 \times 116} = 14.5\text{cm} < t = 17\text{cm}$

- $\varepsilon_p = \frac{d-x}{x}\varepsilon_{cu} + \varepsilon_{pe} = \frac{d-x}{x}\varepsilon_{cu} + \frac{\sigma_{pe}}{E_p} = \frac{105-14.5}{14.5} \times 0.0035 + \frac{7875}{20 \times 10^6} = 0.0222 > 0.015$

- $Mu = 0.93\,\sigma_{pu} \bullet Ap\left(d - \frac{1}{2} \bullet \frac{\sigma_{pu} \bullet A_p}{0.85\sigma c_k \bullet b}\right) = 0.93\,\sigma_{pu} \bullet Ap\left(d - 0.55 \bullet \frac{\sigma_{pu} \bullet A_p}{\sigma c_k \bullet b}\right)$

  $= 0.93 \times 15000 \times 24.1 \times \left(105 - 0.55 \times \frac{15000 \times 24.1}{215 \times 116}\right) \times 10^{-5}$

  $= 326.2$ tm

### 7.4.2 Study of Allowable Stress by the Omani Design Standard

The theoretical calculation (grid calculation method) by the new Omani Design Standards for live loads (60 ton Truck x 2) has been performed for the three representative RC bridges (Bridge No. 1, No. 2, No. 5) and two PC bridges (Bridge No. 6, No. 9). A comparison of the allowable stress and actual stress has also been calculated and presented in Tables 7.28 and 7.29.

**Table 7.28 Calculation Results (Grid) by OMAN Design Standard (RC)**

| Bridge No. | Case No. | | Compressive Strength for Concrete ($kg/cm^2$) | | | | Tensile Strength for Re-bar ($kg/cm^2$) | | | | Deflection (mm) | | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Dead Load $\sigma_{cd}$ | Live Load $\sigma_{cl}$ | Total $\sigma_c$ | Allowable $\sigma_{ca}$ | Dead Load $\sigma_{sd}$ | Live Load $\sigma_{sl}$ | Total $\sigma_s$ | Allowable $\sigma_{sa}$ | Live Load $\sigma_l$ | Allowable $\sigma_{la}$ | |
| 1 | Exterior Beam (G1) | A | 24.0 | 32.2 | 56.2 | $\sigma_{28} = 270kg/cm^2$<br>$\sigma_{ca} = 90kg/cm^2$ | 1009 | 1352 | 2361 | Yield > $40kg/mm^2$<br>$\sigma_{sa} = 1800kg/cm^2$ | 5.1 | | |
| | | B | 24.0 | 26.2 | 50.2 | | 1009 | 1101 | 2110 | | 4.0 | | |
| | Interor Beam (G2) | A | 21.6 | 25.4 | 47.0 | | 1022 | 1201 | 2223 | | 4.8 | | |
| | | B | 21.6 | 24.3 | 45.9 | | 1022 | 1150 | 2172 | | 4.7 | | |
| 2 (3.4) | Exterior Beam (G1) | A | 52.5 | 61.2 | 113.7 | | 1321 | 1539 | 2860 | | 7.8 | | |
| | | B | 52.5 | 52.6 | 105.1 | | 1321 | 1323 | 2644 | | 6.5 | | |
| | Interor Beam (G2) | A | 61.1 | 63.6 | 124.7 | | 1037 | 1079 | 2360 | | 8.1 | | |
| | | B | 61.1 | 61.0 | 122.1 | | 1037 | 1035 | 2072 | | 7.9 | | |
| 5 (8) | Exterior Beam (G1) | A | 55.3 | 65.1 | 120.4 | $\sigma_{28} = 270kg/cm^2$<br>$\sigma_{ca} = 90kg/cm^2$ | 1639 | 1931 | 3570 | Yield > $40kg/mm^2$<br>$\sigma_{sa} = 1800kg/cm^2$ | 7.8 | | |
| | | B | 55.3 | 55.2 | 110.5 | | 1639 | 1638 | 3277 | | 6.4 | | |
| | Interor Beam (G2) | A | 65.1 | 67.6 | 132.7 | | 1283 | 1331 | 2614 | | 8.0 | | |
| | | B | 65.1 | 64.8 | 129.9 | | 1283 | 1276 | 2559 | | 7.8 | | |

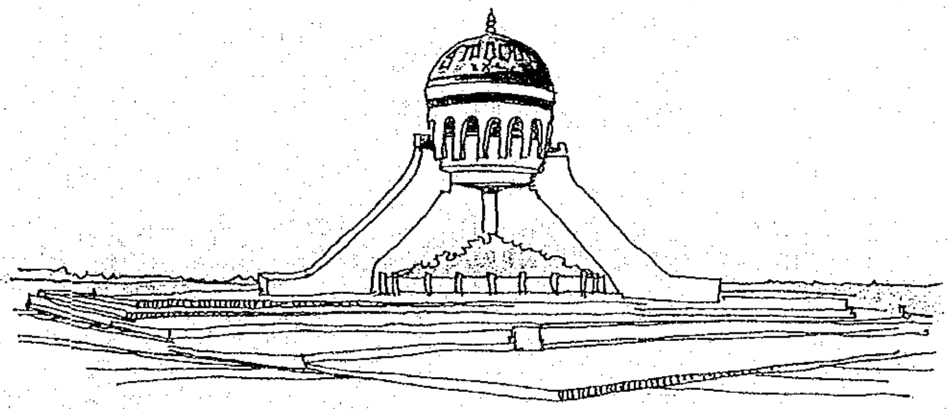
**Table 7.29 Calculation Results (Grid) by OMAN Design Standard (PC)**

| Bridge No. | Girder No. Case No. | Bending Moment (t • m) | | Composite Stress ($kg/cm^2$) | | Deflection by Live Load (mm) | Remarks |
|---|---|---|---|---|---|---|---|
| | | Dead Load | Live Load | Upper Edge of Beam | Lower Edge of Beam | | |
| 6 | Exterior (G1) Case A | 313.7 | 238.7 | 96.2 | -45.6 | 11.2 | |
| | | | | *132.0 | *-13.2 | | |
| | Interior (G2) Case A | 330.8 | 208.7 | 99.8 | -44.4 | 9.8 | |
| | | | | *132.0 | *-13.2 | | |
| | Mix Girder (G1) Case A | Same as G1 | Same as G1 | – | – | 11.2 | |
| | | | | * – | * – | | |
| 9 (7) | Exterior (G1) Case A | 83.4 | 51.5 | 72.9 | -7.6 | 11.0 | |
| | | | | *124.0 | *-12.4 | | |
| | Interior (G2) Case A | 87.7 | 66.7 | 90.3 | -30.3 | 14.3 | |
| | | | | *124.0 | *-12.4 | | |
| | Mix Girder (G4) Case B | 81.8 | 84.0 | 95.1 | -40.5 | 18.0 | |
| | | | | *124.0 | *-12.4 | | |

Note: * indicates the allowable stress by Japan Design Standard

( By ACI Committee $\sigma_{28}$ = 340 $kg/cm^2$ $\sigma_{cu}$ = 153 $kg/cm^2$ $\sigma_{cl}$ = -29.3 $kg/cm^2$
$\sigma_{28}$ = 315 $kg/cm^2$ $\sigma_{cu}$ = 142 $kg/cm^2$ $\sigma_{cl}$ = -28.2 $kg/cm^2$ )

# CHAPTER 8 THE OVERALL EVALUATION OF EXISTING BRIDGES



# CHAPTER 8

# THE OVERALL EVALUATION OF EXISTING BRIDGES

## 8.1 Overall Evaluation

The safety measures for all 9 existing bridges were discussed in the previous chapter.

(1) Evaluation of soundness of existing bridges based on their degree of deterioration

(2) Evaluation of bridges based on testing concrete and reinforcing steel

(3) Evaluation of the bridges using load tests

(4) Evaluation of the bridges based on the load bearing capacity

Each bridge has been appraised according to the overall condition of its superstructure, substructure, and other components. Soundness and load bearing capacity has been described in Fig. 7.1 giving present soundness and future safety measures. Overall soundness is indicated in the following Table 8.1.

**Table 8.1 Summary of Overall Evaluation and Judgement for Bridges**

| Bridge No. | Deterioration from Soundness | Quality of Concrete and Steel Bar | f-Value from Load Test | Load Bearing Capacity | | Overall Evaluation and Judgement (Ao ~ Eo) | | Requirement of Repair |
|---|---|---|---|---|---|---|---|---|
| | | | | Safety Ratio of Ultimate B.M. | Allowable Stress | | | |
| 1 | B | I | I | I | I | Girder<br>Slab | Bo<br>Ao | Record |
| 2 | D | II | III | II | II | Girder<br>Slab | Do<br>Co | Detailed Re-Inspection |
| 3 | C | II | II | II | II | Girder<br>Slab | Co<br>Co | Under observation |
| 4 | E | II | II | II | II | Girder<br>Slab | Eo<br>Do | Emergency Repairs |
| 5 | C | II | III | II | II | Girder<br>Slab | Co<br>Co | Under observation |
| 6 | A | II | I | I | I | Girder<br>Slab | Ao<br>Ao | — |
| 7 | B | I | III | I | III | Girder<br>Slab | Ao<br>Eo | Slab: Emergency Repairs |
| 8 | C | II | III | II | II | Girder<br>Slab | Do<br>Co | Detailed Re-Inspection |
| 9 | B | I | I | I | I | Girder<br>Slab | Ao<br>Do | Slab: Emergency Repairs |

(Notation)

**Overall Evaluation**

| Rating | Condition | Action Taken |
|---|---|---|
| Ao | Sound | — |
| Bo | Fairly Sound | Recorded |
| Co | Fairly Unsound | Condition under observation |
| Do | Not Safe | Make detailed bridge inspection |
| Eo | Dangerous | Make emergency repairs |

**Soundness Determination Table**

| Rating | Condition | Action Taken |
|---|---|---|
| A | No damage noticed. | — |
| B | Small damage noticed. | Damage recorded. |
| C | Damage found. | Conditions under observation |
| D | Large damage found. | Make detailed bridge inspection |
| E | Large damage found. Could be dangerous to the public. | Make emergency repairs |

**Quality of Concrete and Reinforcing Steel**

| Rating | Condition |
|---|---|
| I | Satisfies standard values. |
| II | Equals standard values or is slightly inferior. |
| III | Does not meet standard values. |

**f-Value from Load Test (Calculation/Measurement)**

| Rating | Condition |
|---|---|
| I | Value of f is more than 1.2 for Deflection and Stress. |
| II | Value of f is from 1.0 to 1.2 for Deflection and Stress. |
| III | Value of f is less than 1.0 for Deflection and Stress. |

**Safety Ratio of Ultimate Bending Moment and Load Bearing Capacity**

| Rating | Condition (Girder) |
|---|---|
| I | Safety Ratio is larger than 1.2 for the AASHTO Live Load. |
| II | Safety Ratio is between 1.0 to 1.2 of the AASHTO Live Load. |
| III | Safety Ratio is less than 1.0 of the AASHTO Live Load. |

**Load Bearing Capacity (Allowable Stress, RC)**

| Rating | Condition (Girder and Slab) |
|---|---|
| I | $\sigma_c$ and $\sigma_s$ are both within the allowable stress of the AASHTO Live Load. |
| II | $\sigma_c$ and $\sigma_s$ both exceed the allowable stress of the AASHTO Live Load but are within the $\sigma_{28}$ x 0.75 and $\sigma_{pr}$ (yield point stress) x 0.75. |
| III | $\sigma_c$ and $\sigma_s$ both exceed $\sigma_{28}$ x 0.75 and $\sigma_{pr}$ (yield point) x 0.75 of the AASHTO Live Load. |

## 8.2 Detailed Evaluation of Bridges

An overall evaluation of the bridges together with their adjudication is given in detail in Table 8.2 through Table 8.9.

**Table 8.2 Detailed Evaluation for Bridge No. 1**

| Category | Evaluation Item | |
|---|---|---|
| | Rating | Overall Evaluation & Adjudication |
| Degree of Deterioration | B | There are cracks due to bending of the main girder which have been repaired with epoxy resin mortar.<br>Cracks do not penetrate the girder.<br>No new cracks are observed. |
| Quality of Concrete & Reinforcing bar | I | • Tests indicate concrete to be watertight and dense.<br>• Strength of reinforcing bar exceeds standard strength requirements. |
| f-value from Load Test | I | • f = 1.38 (deflection) concrete and reinforcing bar are both durable and has adequate strength. |
| Load Bearing Capacity: | | |
| Safety Ratio of Ultimate B.M. | I | • Safety Ratio F = 1.33. Considered safe against live loads. |
| Allowable Stress | I | • $\sigma_c$ and $\sigma_s$ are both within allowable limits of safety.<br>• Bridge slab is within allowable limits of safety and considered safe. |
| Overall Evaluation | Girder<br>Bo<br>Slab<br>Ao | • Scheduled inspection of main girder after repair of crack being conducted and indicates both superstructure and substructure are sound. |
| Remarks | | • The repairs made to the bridges are considered inadequate. |

**Table 8.3 Detailed Evaluation for Bridge No. 2**

| Category | Evaluation Item | |
|---|---|---|
| | Rating | Overall Evaluation & Adjudication |
| Degree of Deterioration | D | • Main girder is cracked from bending, and many cracks extend through the girder.<br>• There are many cracks in the concrete slab. |
| Quality of Concrete & Reinforcing bar | II | • Many parts of the concrete are neutralized and is no longer water-tight.<br>• Reinforcing bar exceeds standard strength. |
| f-value from Load Test | III | • f = 0.90 (deflection), cracks in the main girder attributes to the lack of soundness.<br>• Reinforcing bar exceeds standard strength requirements and can carry loads. |
| Load Bearing Capacity: | | |
| Safety Ratio of Ultimate B.M. | II | • Safety Ratio F = 1.17, is sound against Live Loads. |
| Allowable Stress | II | • Main Girder $\sigma_t$ = 89.0 kg/cm$^2$ > $\sigma_{ca}$ = 215 x 1/3 kg/cm$^2$ and exceeds requirements. $\sigma_s$ is within allowable limits.<br>• Both $\sigma_c$ and $\sigma_s$ exceed allowable limits for slab concrete, but $\sigma_{pr}$ and $\sigma_{28}$ are less than 75% of requirement. |
| Overall Evaluation | Girder<br>Do<br>Slab<br>Co | • Reinforcing bar exposed in main girder and rust and scale of reinforcing bar need checking. Restriction of heavy traffic may need to be considered. |
| Remarks | | • Scheduled inspection of main girder and slab should be made for cracks. If cracks increase, consider strengthening with steel sheets. |

**Table 8.4 Detailed Evaluation for Bridge No. 3**

| Category | Evaluation Item | |
|---|---|---|
| | Rating | Overall Evaluation & Adjudication |
| Degree of Deterioration | C | • Main girder has cracks from bending, and many cracks extend through the girder.<br>• Although there are few cracks in the slab, there are cracks on the pavement surface.<br>• Bridge supports are exposed from scouring action of the river. |
| Quality of Concrete & Reinforcing bar | II | • Concrete neutralizing is progressing and is not watertight.<br>• Reinforcing bar exceeds strength requirements. |
| f-value from Load Test | II | • f = 1.07 (deflection), and concrete has durability but the f-value is low due to cracks in the main girder.<br>• Reinforcing bar has sufficient strength and can sustain the bridge live loads. |
| Load Bearing Capacity: | | |
| Safety Ratio | II | • Same as Bridge No. 2 |
| Allowable Stress | II | • Same as Bridge No. 2 |
| Overall Evaluation | Girder Co<br>Slab Co | • Scheduled inspection required for main girder, and load restriction should be considered.<br>• Bridge footings and substructure exposed from scouring and counter-measures should be considered for protection. |
| Remarks | | • Same as for Bridge No. 2. |

**Table 8.5 Detailed Evaluation for Bridge No. 4**

| Category | Evaluation Item | |
|---|---|---|
| | Rating | Overall Evaluation & Adjudication |
| Degree of Deterioration | E/D | • The main girder has cracks from bending of which most pass through the beam, and the bridge can fail. Many cracks appear in the cross beams, slab and pavement (reinforcing bar in the cross beams are corroded). |
| Quality of Concrete & Reinforcing bar | II | • Neutralization of concrete is progressing, and the concrete is no longer water-tight.<br>• Reinforcing bar meets strength requirement. |
| f-value from Load Test | II | • f = 1.15 (deflection) and the rigidity is low due to cracks in main beam, and the f-value is low.<br>• Reinforcing bar exceed standard strength requirements, and are not rusted. |
| Load Bearing Capacity: | | |
| Safety Ratio of Ultimate B.M. | II | • Similar to Bridge No. 2 |
| Allowable Stress | II | • Similar to Bridge No. 2 |
| Overall Evaluation | Girder<br>Eo<br>Slab<br>Do | • Load Limit Restriction should be imposed due to cracks in the main girder, slab panels and reinforcing bar. Bridge needs to be strengthened. |
| Remarks | | • Bridge needs regular inspection, Load Limit imposed, and the bridge should be replaced or strengthened. |

**Table 8.6 Detailed Evaluation for Bridge No. 5**

| Category | Evaluation Item | |
|---|---|---|
| | Rating | Overall Evaluation & Adjudication |
| Degree of Deterioration | C | • There are many cracks from bending and many cracks penetrate the girder, and there are many cracks in the bridge slab.<br>• There are many cracks in the substructure but do not affect the bridge capability. |
| Quality of Concrete & Reinforcing bar | II | • Neutralizing of concrete is progressing and water-tightness is affected.<br>• Reinforcing bars meet the requirements of standard strength. |
| f-value from Load Test | III | • f = 0.90 (deflection), and durability of concrete is affected by the many cracks in the main girder. |
| Load Bearing Capacity: | | |
| Safety Ratio of Ultimate B.M. | II | • Safety Ratio F = 1.18, and is considered safe against Live Loads. |
| Allowable Stress | II | • $\sigma_c$ = 94.8 kg/cm$^2$ and $\sigma_s$ = 2201 kg/cm$^2$ for the main girder and exceeds requirements, and $\sigma_{pr}$ and $\sigma_{28}$ are within 75% of the limits.<br>• The slab also exceeds the requirements, and $\sigma_{pr}$ and $\sigma_{28}$ are within 75% of the limits |
| Overall Evaluation | Girder Co<br>Slab Co | • The main girder requires scheduled inspection due to the existing cracks and traffic restrictions should be considered for the bridge. |
| Remarks | | • Perform scheduled inspection of the bridge and cracks, and if cracks and size increase, consider strengthening with steel sheets. |

**Table 8.7 Detailed Evaluation for Bridge No. 6**

| Category | Evaluation Item | |
|---|---|---|
| | Rating | Overall Evaluation & Adjudication |
| Degree of Deterioration | A | • There are no cracks or damages noticed which can attribute to the lowering of the capacity.<br>The bridge is structurally sound. |
| Quality of Concrete & Reinforcing bar | II | • The neutralizing of concrete is progressing and it is no longer water-tight. |
| f-value from Load Test | I | • f = 1.44 (deflection) and the durability of concrete is sound. |
| Load Bearing Capacity: | | |
| Safety Ratio of Ultimate B.M. | I | • Safety Ratio F = 1.26 and the bridge is sound against Live Loads. |
| Allowable Stress | I | • The slab is within the allowable limits against Live Loads and is considered sound. |
| Overall Evaluation | Girder<br>Ao<br>Slab<br>Ao | — |
| Remarks | | • Due to disfigurement of the shoe scheduled inspection is necessary.<br>• There are no problems in connection with the superstructure or the substructure. |

**Table 8.8 Detailed Evaluation for Bridge No. 7**

| Category | Evaluation Item | |
|---|---|---|
| | Rating | Overall Evaluation & Adjudication |
| Degree of Deterioration | B | • Main girder is sound.<br>• There are no connections between cast-in-place slab panels and precast panels. |
| Quality of Concrete & Reinforcing bar | I | • The concrete has lost some of its strength. |
| f-value from Load Test | III | • f = 0.92 (deflection) and there is loss of durability. Main girder and slab panels seems to have lost some of their durability. |
| Load Bearing Capacity: | | |
| Safety Ratio of Ultimate B.M. | I | • Safety Ratio F = 1.67 and is sound against Live Loads. |
| Allowable Stress | III | • Where cast-in-place slab panels (13cm) and precast slab panels (5cm) are not connected integrally, allowable stress and limit stress are over the limit against Live Loads. |
| Overall Evaluation | Girder<br>Ao<br>Slab<br>Ao | • Due to lack of cross girders to distribute the Live Loads, the superstructure lacks some rigidity. The slab panels are not connected integrally with the precast panels. |
| Remarks | | • Slab should be inspected as often as required, and replaced when any parts are found missing.<br>• It is strongly recommended to add cross girders at supporting ends of the main girders to increase rigidity. |

**Table 8.9 Detailed Evaluation for Bridge No. 8**

| Category | Evaluation Item | |
|---|---|---|
| | Rating | Overall Evaluation & Adjudication |
| Degree of Deterioration | C | • Many cracks in main girder, slab panels and cross girders; many cracks in main girder extend through the girder (reinforcing bar are rusted).<br>• Substructure is damaged from flowing rocks and sand. |
| Quality of Concrete & Reinforcing bar | II | • Water absorption and water concrete is high and concrete is not water-tight.<br>• Reinforcing bar meets strength requirements. |
| f-value from Load Test | III | • f = 0.94 (deflection) and concrete does not meet strength requirements due to many cracks in main girder.<br>• Reinforcing bar exceeds strength requirements and is satisfactory. |
| Load Bearing Capacity: | | |
| Safety Ratio of Ultimate B.M. | II | • Same as Bridge No. 5 |
| Allowable Stress | II | • Same as Bridge No. 5 |
| Overall Evaluation | Girder Ao | • Scheduled inspection necessary due to many cracks in main girder. Should consider load restriction on bridge. |
| | Slab Ao | • Repair substructure (meets with strength requirements. |
| Remarks | | • Inspect superstructure for cracks and if increase is noticed, check reinforcing bar for rust, and consider strengthening by repairs. |

**Table 8.10 Detailed Evaluation for Bridge No. 9**

| Category | Evaluation Item | |
|---|---|---|
| | Rating | Overall Evaluation & Adjudication |
| Degree of Deterioration | B | • Main girder is sound.<br>• Some lower precast slab panels are damaged.<br>• Some of the substructure is damaged. |
| Quality of Concrete & Reinforcing bars | I | • Neutralization of concrete is progressing and is lacking in water-tightness. |
| f-value from Load Test | I | • f = 1.54 (deflection) and super-structure is sound. |
| Load Bearing Capacity: | | |
| Safety Ratio of Ultimate B.M. | I | • Same as Bridge No. 7 |
| Allowable Stress | I | • Cast-in-place slab panels (13cm) are integrally connected with precast slab panels (5cm), so actual stress is within allowable requirements. |
| Overall Evaluation | Girder<br>Ao<br>Slab<br>Ao | • Bridge lacks rigidity due to no cross girders to distribute loads, and bridge slab is a combination of cast-in-place and precast slab panels but are not integrally connected. |
| Remarks | | • Perform scheduled inspection of slab panels, and if any are found missing, make structural changes to bridge.<br>• Add cross girders at main girder supporting ends to increase rigidity to bridge. |

## 8.3 Control of Heavy Vehicle Traffic on the Bridges due to the New Design Live Load

The new Omani design standards for the live loads are as follows:

(1) Twice the current AASHTO HS20-44 live load system

(2) The live load system with two Omani 60 ton Truck Loads running in parallel in adjoining lanes.

The theoretical calculations for the above changes have been performed for the existing RC and PC bridges in Chapter 7. As the live load systems for the existing bridges in Oman were performed in accordance with the design loads established by the U.S. AASHTO live load specifications, the calculation methods for the main girder and slab are as follows:

- Main Girder

| | | | |
|---|---|---|---|
| 1) | AASHTO HS20-44 Live Load | : | Load Bearing Ratio (α), Rupture Safety (F) |
| 2) | Twice the Live Load of AASHTO HS20-44 x 2 | : | Load Bearing Ratio (α), Rupture Safety (F) |
| 3) | Live Load of Oman Truck 60 Ton x 2 | : | Actual Load Capacity and Allowable Values |

- Slab

| | | | |
|---|---|---|---|
| 1) | 7.0 Ton Wheel Load by Load Tests | : | Actual Load Capacity and Allowable Values |
| 2) | AASHTO HS20-44 Live Load 7.26 Wheel Load (Hi) | : | (Same as above) |

### 8.3.1 Load Bearing Capacity of Main Girder

The Rupture Safety Factor (F) of 9 bridges are all in excess of 1.0 against the present live load of AASHTO HS20-44 under the original design, and the main girders have strength to spare.

Under the revised new design criteria of AASHTO HS20-44 x 2, with the exception of the two PC bridges No. 7 and No. 9, the Rupture Safety Factors (F) are all less than 1.0 and there is no spare load capacity for the main girders.

Hence, from the restrictions of live loads for the main girders, the rear axle load will be less than 14.52 ton for the AASHTO HS Truck, and will be similar to the axle load stated in Chapter 7.4.1, 1) b).

For the live load system under the Oman Truck 60 Ton x 2 case, the bridges have not the load capacities.

- Oman Truck 60 Ton x 2 Live Load Case

  The existing RC and PC bridge load capacities all exceed the allowable value of the actual load capacity. Even when the values exceed the allowable values, they can be accepted as the stress prior to deformation, and the values given in Chapter 6 can be used as a guide.

| | |
|---|---|
| Bending Stress in Concrete | $\sigma_c \leq \sigma_{28} \times 0.75$ |
| when | $\sigma_{28} = 270\ kg/cm^2$, $202\ kg/cm^2$,<br>$\sigma_{28} = 215\ kg/cm^2$, $161\ kg/cm^2$. |
| Tensile Strength of Reinforcing bar | $\sigma_s \leq \sigma_{pr}$ (Yield Point) x 0.75 = 3,150 kg/cm$^2$<br>or<br>$\sigma_{pr} = 4{,}200\ kg/cm^2$. |

From the above, the stresses in RC bridges do not exceed the limits of stress ($\sigma_{28}$ x 0.75, $\sigma_{pr}$ x 0.75). But when there are many cracks in the main girders and slab the live load system is not suitable. In PC bridges the stresses in the lower side of the main girders will be in excess of the allowable limits, and under the live load system it is easier for cracks to propagate in the future.

### 8.3.2 The Allowable Load Capacity of Slab

The slab load capacity has been given in Table 7.24 in the previous chapter for the present live load under the present AASHTO HS20-44 for the original design conditions. The rear axle load P20 = 7.26 (1 + i) ton the load will be slightly in excess of the allowable stress except for Bridge No. 6, and against wheel load systems for repeated stresses and fatigue loads the load bearing capacities fall with the result that there are more cracks and failures in the slab planks causing traffic problems. PC Bridges No. 7 and No. 9 have structural problems with their slabs construction, and apart from their load bearing capacities, the replacement of their decks is recommended.

### 8.3.3 Recommendations to Restrict Traffic on Bridges

The superstructure of the bridges consisting of the main girder and concrete slabs were checked for a maximum rear axle load of 17.60 tons at the time of traffic survey. In checking against the load capacity and stresses, the present AASHTO live load is the maximum load that the bridges can bear.

For this reason, the bridges on main trunk routes and where the bridge damage is great, it is recommended to perform axle load checks from time to time, and as described in the previous chapter, to post a sign on the bridge for an axle load limit in accordance with AASHTO HS20-44. However, limited axle load in Omani regulation is 13.0 ton maximum as shown in Fig. 8.1.

It is proposed that the bearing capacity of axle load and total truck load for 9 bridges shall be restricted for both the main girder and the slab as listed in Table 8.11.

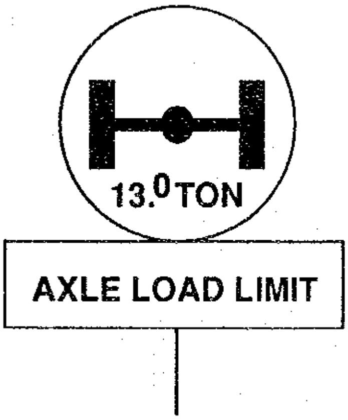



**Fig. 8.1 Example for Sign of Axle Limit**

**Table 8.11 Capacity of Axle Load and Total Truck Load for 9 Bridges**

| Bridge No. | Slab (Axle Load) Ton | Girder (Total Truck Load) Ton |
|---|---|---|
| Br. No. 1 | 14.5 | 32 (Equivalent AASHTO HS20-44) |
| Br. No. 2, 3, 4, 5, 8 | 10.8 | 24 (Comparing AASHTO HS20-44) |
| Br. No. 6 | 14.5 | 32 (Equivalent AASHTO HS20-44) |
| Br. No. 7, 9 | 10.8 | 24 (Comparing AASHTO HS20-44) |

### 8.3.4 How to Maintain Bridges in Oman under the New Live Loads

The existing 9 bridges and other bridges on the main trunk roads are of RC and PC construction all with similar types and spans. These bridges were planned using the AASHTO design standards at the time of their original construction, and the vehicles have grown larger and heavier while the bridges themselves have grown older. New and improved design standards for live loads passing over the main girders and concrete slab are required to bear further damaging loads.

In order to ensure the existing bridges for further continued use, it is necessary to take protective measures from circumstantial forces that cause the bridges to deteriorate by restricting heavy weight vehicles and rerouting special vehicles to other routes, making special inspections and special checks of the bridges, and make immediate repairs to the bridges depending on the degree of damage caused.

# CHAPTER 9 PROPOSED REPAIR PLAN FOR EXISTING BRIDGES

# CHAPTER 9

# PROPOSED REPAIR PLAN FOR EXISTING BRIDGES

## 9.1 Repair Plan

The repair of damages to bridges will differ with the damages sustained by the bridges, usage and the surrounding conditions of the bridges, and the degree of damage to the bridge components. The methods to be used and the degree of repair will suit the various conditions.

The repairs to be performed will be based on the results of the damage or disorders revealed by the investigation. Repair required will be based on the load tests, durability of the structure, and the safety of the bridge, and be suitable for the damaged components, the degree, and cause of the damage.

1) The Classification of the Damage Corrective Measures

The method of repairs to the damages can be classified into the repair, reinforcement or replacement depending on the degree of the damage.

- Corrective Methods
  - Repair — To restore the function of the bridge excepting durability, watertightness and strength.
  - Reinforcement — To upgrade the damaged component to its original strength and cross section, add or replace the component to sustain the generated stress, or restore the loss of strength against loads.
  - Replacement — To replace the bridge if parts of the bridge are determined to be irrepairable or too costly to strengthen for the component (superstructure or substructure) to maintain the durability or safety.

## 1. Selection of Corrective Measures

In general damaged bridges are restored by either performing repairs or strengthening. However, depending on the degree of damage, in order to maintain the structural reliability, economics and administratively it may be more effective to replace the bridge outright. The selection of the corrective measures may be better than to simply repair or strengthen the bridge, and it will be important to view the situation from an overall viewpoint.

### (1) Structural Studies

In making repairs or strengthening of the bridge components, it will be necessary to remove the cause of the damage of the bridge by determining the factors which brought about the damage. It will be important to find out whether the materials required to make the repairs or strengthening are available, and to make the necessary of the records and files pertaining to the bridge. For this study the following materials will be required:

- As-built drawings and documents
- Files and records of the bridge
- Records of bridge repairs
- Records of detailed bridge examinations

### (2) Discussions to Select Bridge Repair Methods

Discussions will be required to be held to decide the construction methods:

- Conditions at the bridge site
- Methods of construction
- Time required to make repairs
- Detours and other traffic monitoring methods
- Types of vehicle traffic and restrictions
- Safety of pedestrians around construction site

### (3) Administrative Discussions

Discussions should be held for overall studies of future bridge plans, improvements and repairs to the river, importance of the road route over the bridge (emergency transport routes, by-pass roads), etc.

(4) Economic Studies

The most economical method of construction should be studied.

(5) Other Related Matters

Alternate methods of construction should be studied together with other related matters.

The selection of other methods can be selected as described in Fig. 9.1.

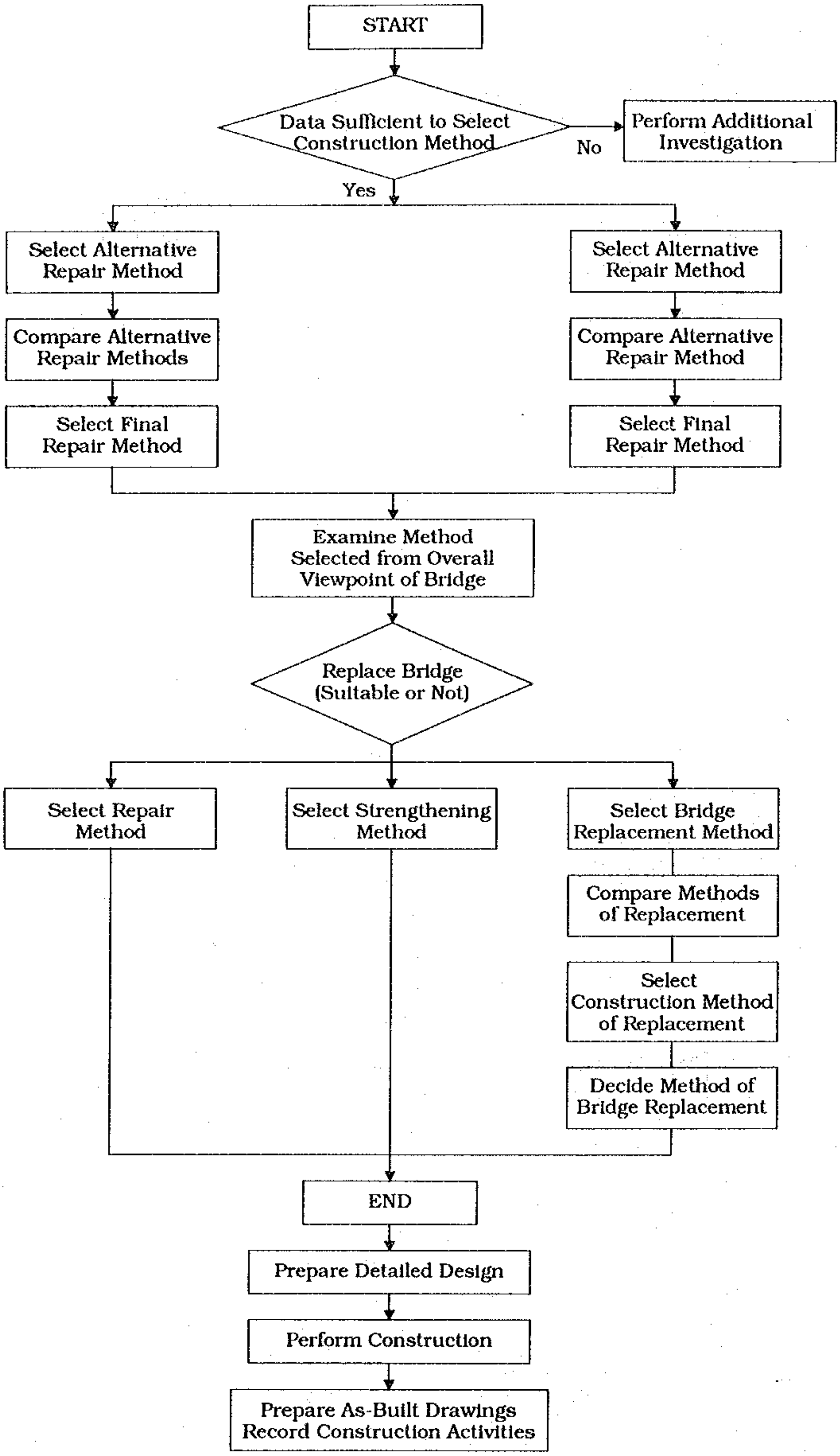



**Fig. 9.1 Flow of Selection of Alternative Methods**

## 2. Structural Components of Bridge

The structural components of reinforced-concrete bridges have been broken down into the classification given in Fig. 9.2 to make the selection of construction methods easy.

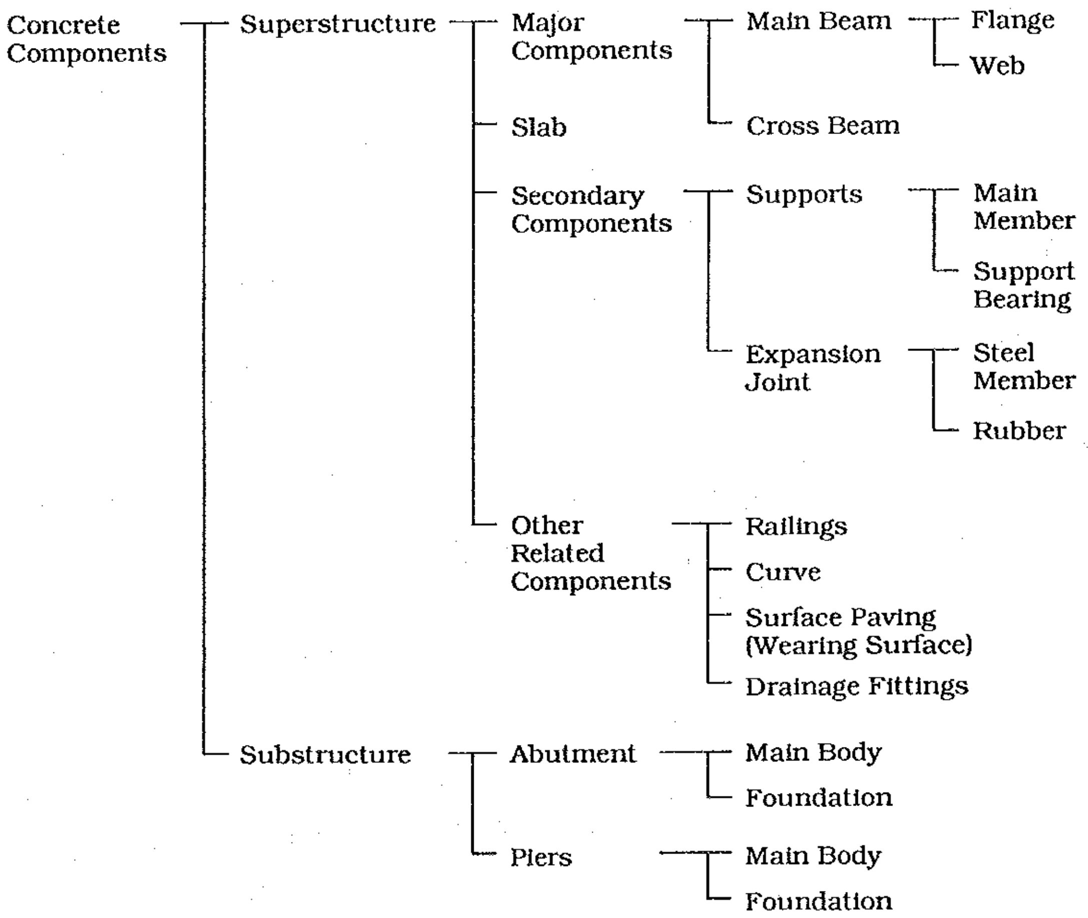



**Fig. 9.2 Structural Components of Bridges**

## 3. Damage to Structural Components

Although the damage to the structural components of bridges and the causes thereto differ, the damages sustained do have some common features.

The relation of structural components and the relation of damages sustained can be described in Table 9.1.

**Table 9.1 Concrete Bridge Components and Damages Sustained**

<table>
<tr><th colspan="2">Structural Component</th><th>Damages Sustained</th></tr>
<tr><td rowspan="6">Common Concrete Component</td><td>Main structural member</td><td>Cracks</td></tr>
<tr><td>Slab</td><td>Delamination, exposed reinforcing</td></tr>
<tr><td>Secondary concrete members</td><td>Popouts, honeycombs</td></tr>
<tr><td>Other concrete members</td><td>Colouring, deterioration</td></tr>
<tr><td>Abutments, pier concrete columns</td><td>Water leaks</td></tr>
<tr><td>Abutment, pier footing and foundation</td><td>Breakage, cracks</td></tr>
<tr><td colspan="2">Main concrete member</td><td>Abnormal vibration, bending</td></tr>
<tr><td colspan="2">Secondary concrete members</td><td>Base subsiding</td></tr>
<tr><td colspan="2">Footing and Foundation:<br>Foundation<br>Pile Footings<br>Caisson Foundation</td><td><br>Subsiding<br>Horizontal shifting<br>Overturning, scouring</td></tr>
</table>

## 4. Selection of Repair and Strengthening Method

In selecting the method of repair or strengthening it will be important to find the method best suited for the cause of the damage. The methods for repair and strengthening are given in Tables 9.2 and 9.3.

**Table 9.2 Methods to Correct Damage to Concrete Members**

| Type of Correction | | Corrective Method: Code | Corrective Method: Method Name |
|---|---|---|---|
| Repairs: | | | |
| (1) Remove Defective Parts or Recast or Fill | Small Scale | (a) (b) | (a) Surface Repair |
| | Large Scale | (e) (f) | (b) Injection |
| (2) Cover Cracks | | (a) | (c) Grouting |
| (3) Fill Cracks | Width Small | (b) | (d) Batching Method |
| | Width Large | (c) | (e) Mortar Spray |
| (4) Add Concrete | | (e) (f) | (f) Prepact Method |
| (5) Fill with Precast Grout | | (i) | (g) FRP Adhesive |
| (6) Waterproof with Surfacing and Seal from Exterior Atmosphere | | (g) (k) | (h) Chloride Cathodic Protection |
| (7) Corrosionproofing or Cathodic Protection | Salt Attack | (h) | (h) Neutralization |
| | Neutralization | (i) | (i) Stop Reaction with Cl Aggr |
| | Reaction with Cl Aggr | (j) | k) Waterproofing |
| (8) Repainting | | (m) | (l) Inject PC Grout |
| (9) Construct Barriers or Install Signs | | (n) | (m) Painting |
| | | | (n) Other Methods |
| Strengthening: | | | |
| (10) Increase Cross Section of Concrete | | (t) | (o) Concrete Addition |
| (11) Strengthen by Adding Reinforcements | | (p) (q) | (p) Add Steel Plate |
| (12) Replace with New Materials | | (o) | (q) Add Prestressing |
| (13) Increase Materials, Reduce Reaction | | (s) (r) | (r) Layer Method |
| (14) Change Shape of Structure | | (s) | (s) Increase Mtls |
| (15) Consider Change of Structure or Develop New Shape of Structure | | (u) | (t) Increase Cross |
| (16) Restrict Traffic Load | | (v) | (u) Study, Develop New Method |
| | | | (v) Other Methods |

**Table 9.3 Foundation Corrective Methods**

| Type of Correction | Corrective Method | |
|---|---|---|
| | Code | Method Name |
| Strengthening: | | |
| (1) Strengthen by increasing concrete and/or steel volume | (a) | (a) Addition Method of Member |
| (2) Strengthen of stability by extend of footing | (a) | (b) Strut Method |
| (3) Reinforce of member which reduce the horizontal force | (b) (c) | (c) Additional Piles Method |
| (4) Reinforce of member which strengthen the horizontal and vertical force | (c) | (d) Earth Pressure Reduction Method |
| (5) Reduce of earth pressure | (d) | (e) Protective Piles Method |
| (6) Strengthen of bearing ground | (f) | (f) Earth Improvement Method |
| (7) Construction of protection structure or river bed | (g) | (g) Foot Protection Method |
| (8) Countermeasure against to negative friction | (e) | (h) Develop and Study of New Method |
| (9) Replacing of concrete | (a) | |
| (10) Develop or study of new structural type | (h) | |

## 5. Methods of Repair and Strengthening of Concrete Bridges

### 1) Repair and Strengthening Methods for Concrete Members

#### a. Surface Repair Methods

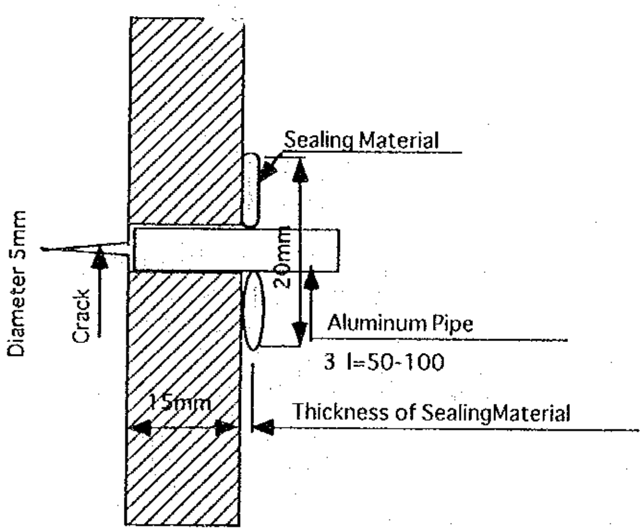
This method is best suited for repair of cracks less than 0.2 mm wide.

When the cracks are small or show no signs of progressing, apply a coat of resinous material or cementitious material over the cracked surface to enhance the waterproofing and durability of the concrete member.

#### b. Injection Method

This method is to inject the resinous material or cementitious material in to the crack to prevent the entry of air and water and prevent the corrosion and deterioration of reinforcing bars.

This method will allow the parent concrete to regain some of its strength which had been reduced by cracks.




| Crack Width (mm) | Pipe Interval |
|---|---|
| Under 0.3 | 50 - 100 |
| 0.3 - 0.5 | 100 - 200 |
| 0.5 - 1.0 | 150 - 250 |
| Over 1.0 | 200 - 300 |

**Fig. 9.3 Injection Method**

c. Grouting Method

Use when the cracks are more than 0.5 mm wide.

This method is to cut the concrete surface along the crack and fill the crevice with resinous material or cementitious concrete repair materials.

(1) When the Reinforcing Bars are Not Corroded

Cut the concrete along the concrete in a "U" or "V" shape approximately 10 mm wide, and fill with the repair material.

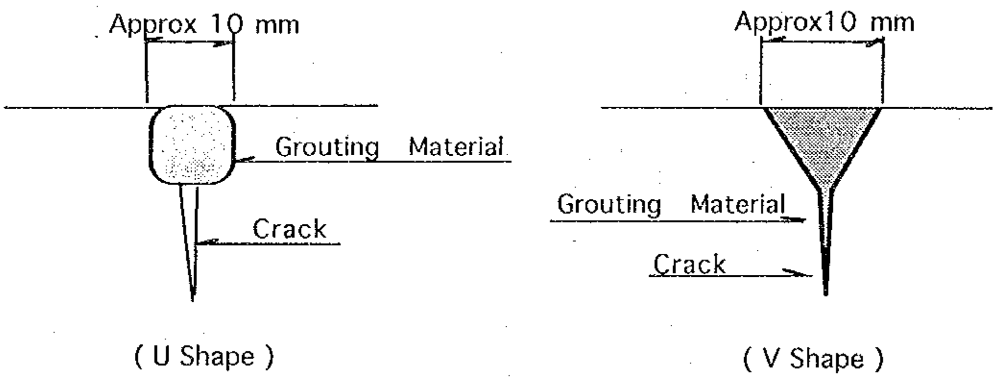



**Fig. 9.4 Repair Method When Reinforcing Bar is Not Corroded**

(2) When the Reinforcing Bar is Corroded

Remove the concrete along the corroded bar, remove the rust from the bar with a cleaning agent, apply a primer and apply repair material.

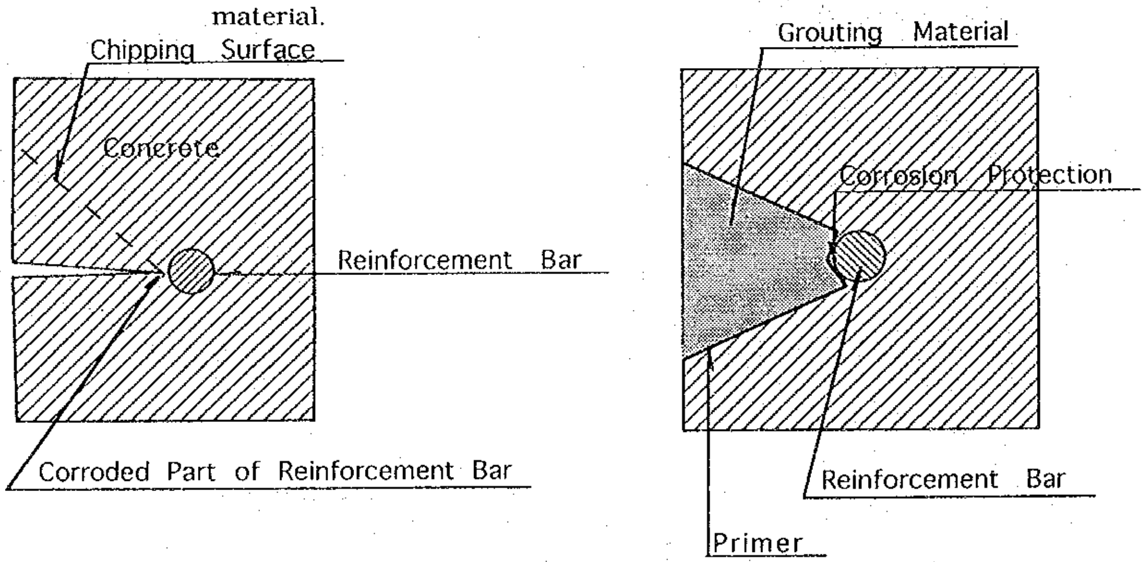



**Fig. 9.5 Repair Method When Reinforcing Bar is Corroded**

d. Batching Repair Method

This method is used to repair delaminated or deteriorated concrete surfaces, and consists of filling the void in the concrete with cement mortar or concrete.

e. Repair with Gun Applied Mortar

This method consists of applying cement mortar or concrete with compressed air.

f. Prepakt Method

This method consists of filling pre-selected rough aggregates into a form and filling the interstices in the aggregate with cement mortar or resinous material.

g. Adhesive Applied FRP Method

This repair method consists of applying Fiber Reinforced Plastic (FRP) materials with adhesive to the concrete surface. The FRP material is used instead of the steel panel in the Adhesive Applied Steel Panel and is used to enhance the waterproof and corrosion of the concrete surface.

h. Chloride Corrosion Prevention Method

This method is used to remove the chloride ions within the concrete electrically.

i. Prevention of Neutralization of Concrete

This method consists of applying a coat of penetrating primer or a silicate on the concrete surface to cure concrete cracks and joints to prevent water seepage or flow, by restoring the alkalinity of concrete which has become neutralized.

j. Prevention of Chloride Reaction in Aggregates

In order to prevent the chloride ions in aggregates from reacting with water, the water penetrating into the concrete can be prevented by injection of gels and application of waterproofing agents on the surface of the concrete.

k. Application of Waterproofing Agents

This method consists of applying or gluing on waterproofing materials to the concrete surface.

l. Injection of PC Grout

This method consists of injecting grout into the sheath of the prestressing tendons.

m. Painting Method

This method consists of painting the surface of the deteriorated concrete to improve the appearance of the concrete.

n. Other Methods

Construct protective facilities or install warning signs.

o. Replacing of Concrete

This method consists of replacing a part or all of the damaged concrete with new concrete in order to improve the durability and strength.

p. Steel Panel Application Method

This method consists of applying a steel panel on the surface of the tension side of the structural concrete member to become an integral part of the member and increase its strength.

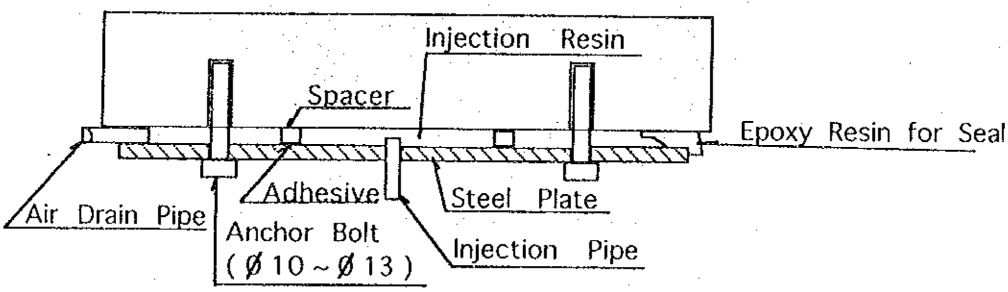



**Fig. 9.6 Steel Plate Application Method**

q. Prestress Introduction Method

This method consists of introducing prestress to existing structure and reducing tensile stress in the member by application of compressive strength.

It is possible to increase the durability and the rigidity of the member, and decrease the widths of cracks.

r. Member Lamination Method

This method consists of adding an additional member and support the member and thereby increase the strength of the member.

s. Member Adding Method

This method consists of adding an additional beam, slab or cross beam and thereby increase the strength of the member.

(1) Beam Adding Method:

| | | |
|---|---|---|
| • Main Beam Adding Method | : | Add another beam and increase the strength. |
| • Longitudinal Beam Method | : | Add additional longitudinal beams and increase the strength of deck panels. |
| • Cross Beam Method | : | Add additional cross beams and increase the strength of the overall structure. |

(2) Column Adding Method:

Add additional columns at the midpoint of beams to decrease the span of the beam to increase the load bearing capacity.

t. Cross Section Increase Method

This method consists of increasing the cross section of the structural steel or the concrete member and thereby increase the load bearing capacity of the member.

u. Study and Development of New Methods

Study and development of new methods of repair and strengthening for the safety, durability and constructability.

v. Other Methods

Depending on the degree of damage to the bridge and the cause of the damage, emergency methods become necessary. Restrict the traffic on the bridge.

- Limit passage of heavy vehicles
- Close the bridge to all types of vehicles

2) Methods of Strengthening Sub-structure

a. Increase Cross Sectional Area of Member

In order to increase the capacity and strength of the concrete member, remove a part of the damage or whole of the member and replace with new concrete.

b. Strut Support Method

In order to arrest further changes of the foundation, install struts to connect the foundation to make it stable.

c. Drive Additional Piles

In order to make the foundation more stable, and add to the number of piles or inadequate penetration of piles, drive additional piles to strengthen the foundation.

d. Decrease Earth Pressures

In order to reduce the pressure of earth backfills on the abutments or subsiding of the abutments, remove the existing backfill earth and increase slab beams or culverts to strengthen the structure.

e. Additional Protective Pile Method

Drive new piles around existing pile foundation and reduce negative skin friction.

f. Soils Improvement Method

Strengthen the load bearing capacity of the foundation soils and prevent further subsiding of foundation and footings.

g. Strengthening of Foundation

Protect the bridge foundation from lowering of the river bed or scouring action. The improvement of the foundation will differ with the characteristics of the river.

(1) Protection of the Foundation with Gabions:

Use this method when the river bed is not stable. (see Fig. 9.7)

(2) Protection of the Foundation with Concrete Blocks:

Use this method when the degree of river bed stability is comparatively small. (see Fig. 9.8)

(3) Protection with Poured Concrete:

Use this method when the width of the river is small and river bed is not stable but the depth is small. (see Fig. 9.9)

(4) Placement of Protection Stone in Forms:

Use this method of foundation protection when the river bed is stable and depth of protection is small.

(5) Protection with Cast Stone:

Use this method of protection when the flows in the river is rapid and there is local scouring. (see Fig. 9.11)

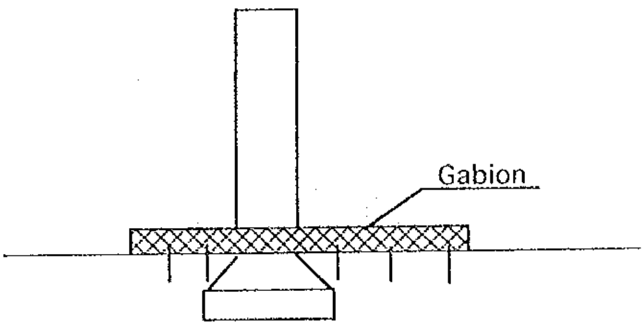



**Fig. 9.7 Protection with Gabions**

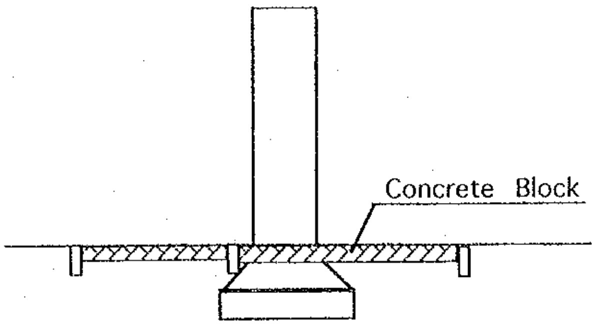



**Fig. 9.8 Protection with Concrete Blocks**

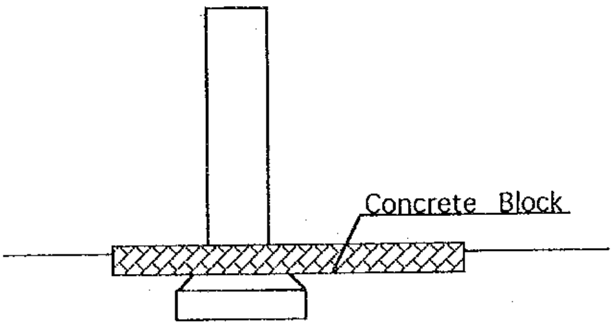



**Fig. 9.9 Protection with Concrete Slabs**

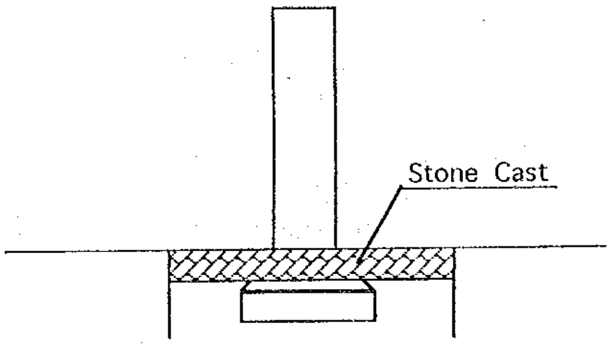



**Fig. 9.10 Protection with Stone Cast in Forms**

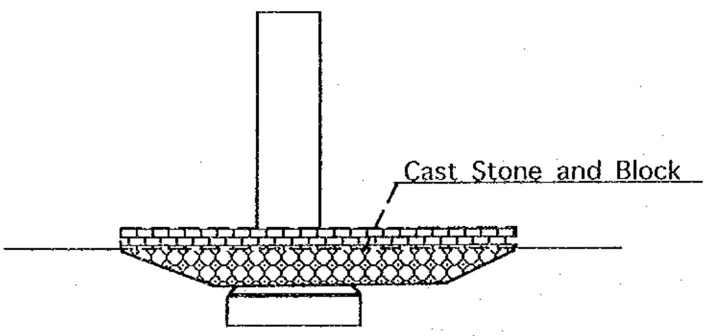



**Fig. 9.11 Protection with Cast Stone and Blocks**

h. Research and Development of New Methods

Develop new methods of maintenance and repair which are safe, durable and easy to construct.

## 9.2 Bridges Requiring Emergency Repairs

Existing bridges evaluated in Chapters 7 and 8 for their overall safety, and those that require emergency repairs or reinforcing will be considered for treatment as follows:

### 1. Bridges Requiring Immediate Action

1) Bridge No. 4 (Wadi Al Jizi Dah-7/202-27)

The concrete has neutralized and is no longer watertight. Load tests indicate lowering of the rigidity ($f = 1.15 > 1.0$), and it is assumed that the cracks in the main girder contribute to this. Route No. 7 where the bridge is located has heavy traffic, and a check of the axle weights indicate heavy vehicles (58.1 ton) make up a greater part of the traffic and is expected to increase further.

(1) Cracks in Concrete

① There are cracks on the bottom side of the main girder near the center of the span of 1.2 mm to 3 mm, and the reinforcing bar is corroded. This indicates that the bridge is deteriorated in general and the capacity has lowered and is in a dangerous condition.

② There are cracks in the web and flange of the main girder due to bending and shear action, and the cracks extend through the beam and is in a dangerous condition.

③ There are cracks in the bottom side of the cross beam and slab.

④ There are also many cracks in the substructure.

(2) Causes of Deterioration

The bridge was designed in accordance with AASHTO HS20-44 32t, and vehicles exceeding this loading use the bridge and contributed to the generation of the cracks.

(3) Method of Repair

The following methods of repair are recommended to repair cracks in concrete, rebar corrosion, and neutralization of the concrete.

① Injection method
② Patching method
③ Neutralization protection method

(4) Strengthening Method

① Laminating Method

- Add new materials to the underside of the main girder and strengthen the girder. (Fig. 9.12)
- Construct a box culvert under the main girder and support the girder. (Fig. 9.13)

② Adding Support Method

- Construct a pier at the midpoint of the girder span and shorten the span. (Fig. 9.14)

③ Restrict Load and Limit Traffic on Bridge

- Restrict passage of heavy vehicles.

④ Replace Bridge

- Replace main girder and deck panels of the superstructure.

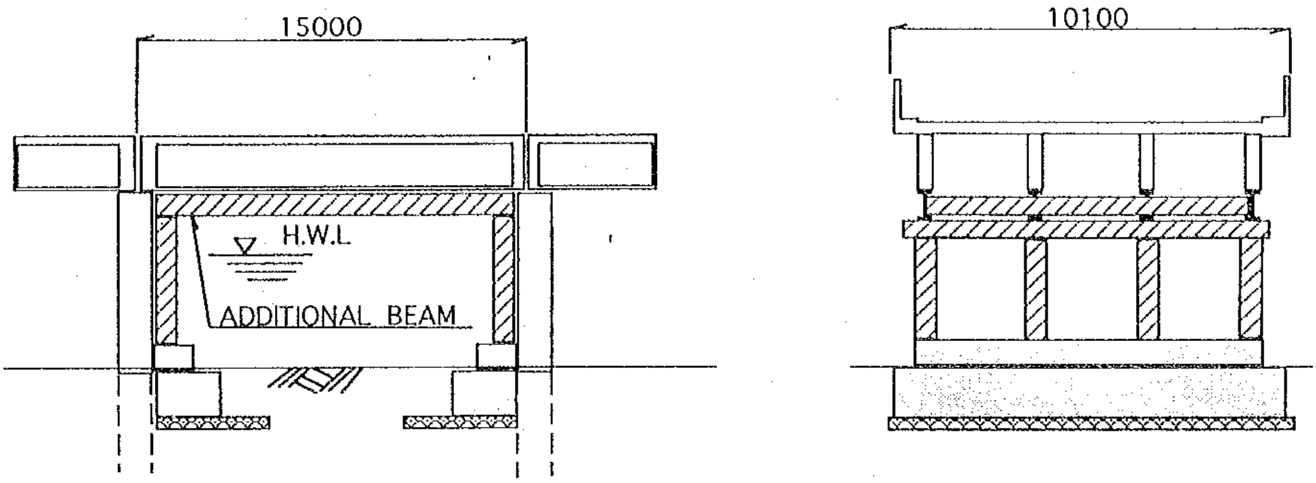



**Fig. 9.12 Strengthening Method by Additional Beam**

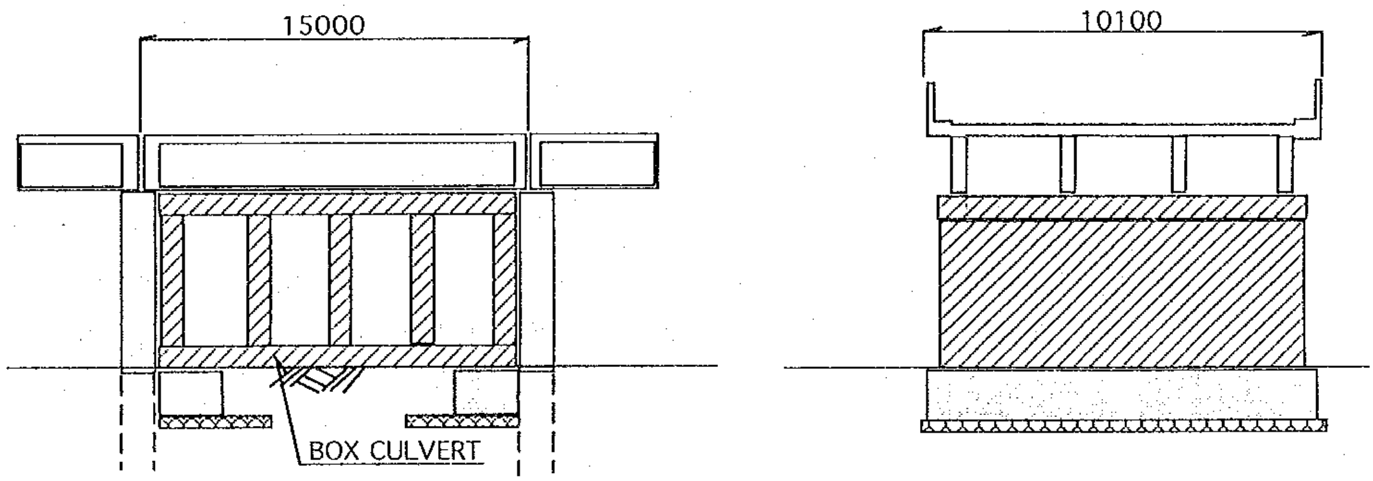



**Fig. 9.13 Strengthening Method by Box Culvert**

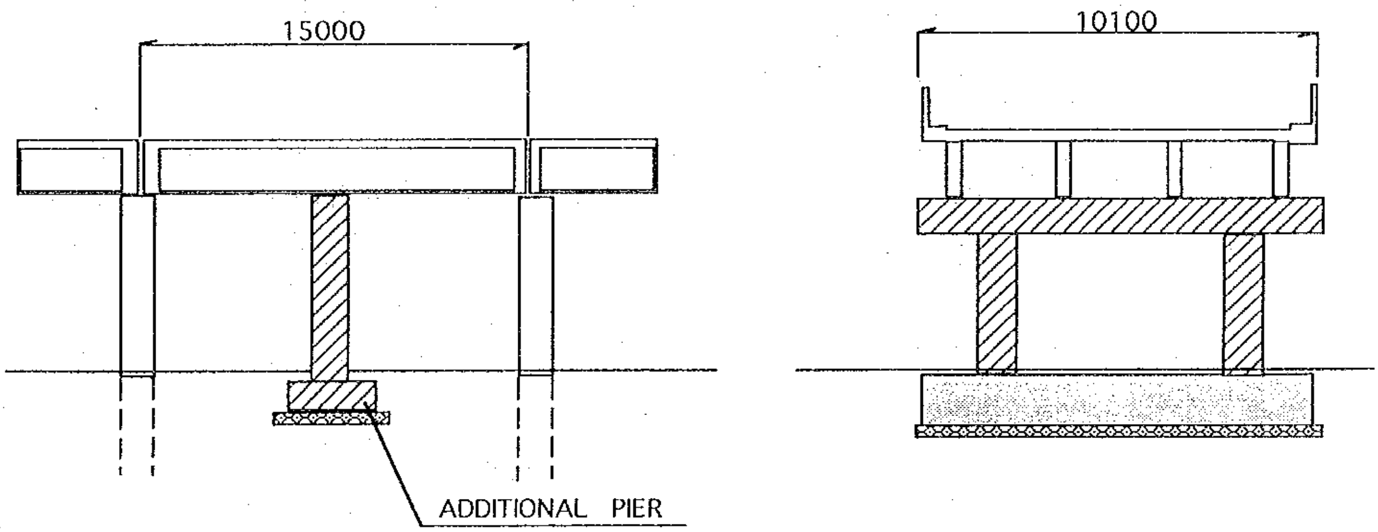



**Fig. 9.14 Strengthening Method by Additional Pier**

The following countermeasures for bridge No. 4 were carried out by Directorate General of Roads (DGR) as maintenance work in 1994.

(1) Restriction of Heavy Vehicle

Heavy vehicle should be detoured and ultimate strength reduced.

(2) Mortar Injection to Cracks of Main Beam, Slab and Cross Beam

① Progress of crack under condition of heavy vehicle loading should be inspected by routine inspection.

② Re-corrosion and progress of neutralization of reinforcement bar should be prevented.

For the other bridges, following the proposed repair plan, maintenance work will be carried out in order and soundness of bridge as judged by inspection items.

2) Bridge No. 7 (Bidbid Sur Dak-23/100-2)

This bridge was tested by a load test which revealed that the concrete has a reduced rigidity ($f = 0.92 < 1.0$), and this is due to the loss of rigidity of the main girder and the concrete slab. The bridge is located on National Road Route 23 and the traffic consists of heavy vehicles (49.9 ton). Traffic volumes are heavy, and expected to become heavier.

(1) Structural Problems

There are no cross beams to distribute the loads with the result that the main girder is required to carry the load thereby lowering its rigidity.

(2) Problems of the Slab

The deck panel is a precast concrete panel (5 cm) over which a concrete slab (13 cm) has been poured for a total of 18 cm thick slab, but the two layers have not formed an integrated panel to act as a single concrete slab.

(3) Reinforcement Plans

① Adding of Material Method

- Add cross beams at both end of supports and a beam at midpoint to distribute the load. (Fig. 9.15)

② Replacement of Concrete

- Remove and replace concrete slab over the precast panel to form an integral concrete slab.

③ Enforce Load Restrictions and Limit Traffic

- Restrict heavy vehicle traffic.

## 2. Future Repairs and Reinforcement of Bridges

A survey of the existing bridges indicate that there are no bridges that require immediate repairs or reinforcement, but in making bridge inspections in the future there may be bridges that will require repairs and reinforcement and suitable methods are suggested in the following.

However, the reinforcement of the cross beam for bridges No. 7 and No. 9 are required as shown in Fig. 9.16 in detail.

1) Bridge No. 2 (Wadi Al Jizi Bat-7/102-02)

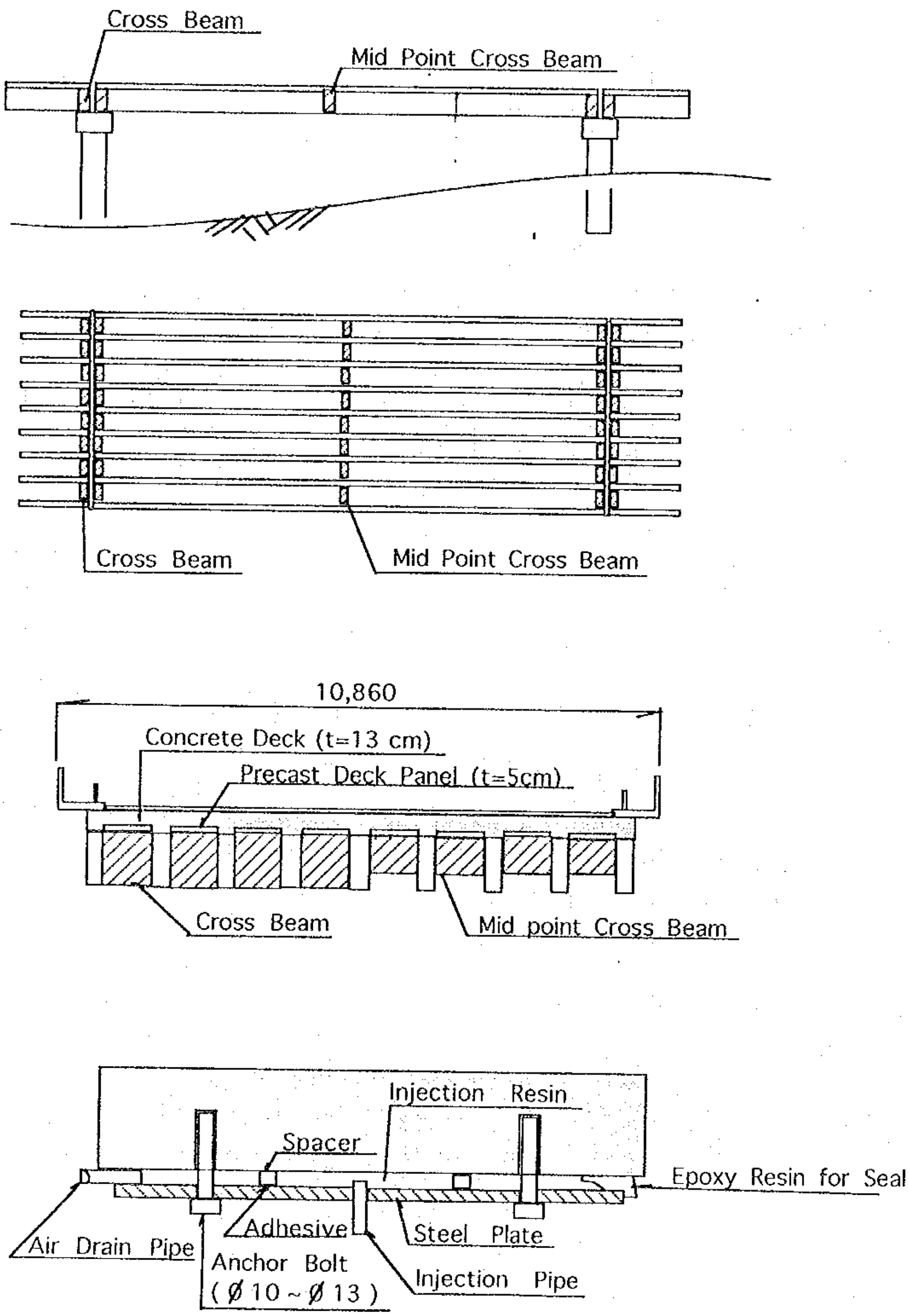
The concrete in this bridge has advancing neutralization and there is loss of watershedding. Load tests indicate loss of rigidity of the concrete ($f = 0.90 < 1.0$), and this can be attributed to the cracks in the main girder. The bridge is located on National Road Route No. 7 where there is heavy traffic of heavy vehicles, and is expected to increase.

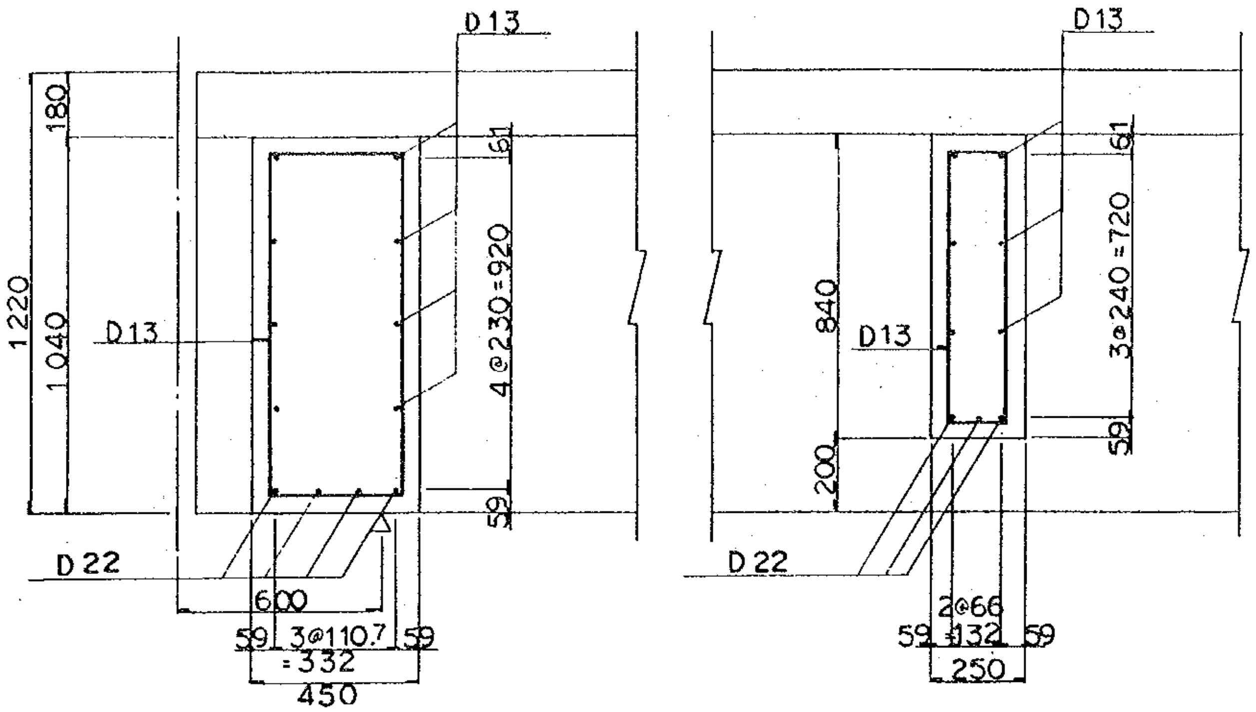
(1) Cracks in the Concrete

① There are cracks (less than 0.2 mm) in the main girder due to its bending action, and some cracks extend through the girder.

② There are cracks on the lower face of the cross beams and slab.

**Fig. 9.15 Adding of Material Method**



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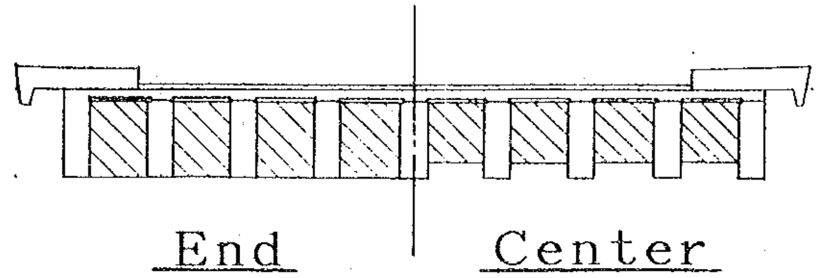

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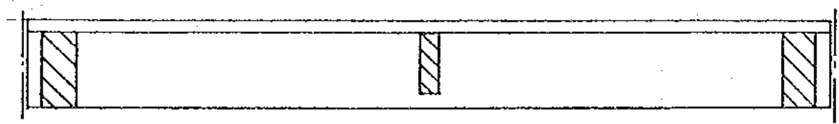
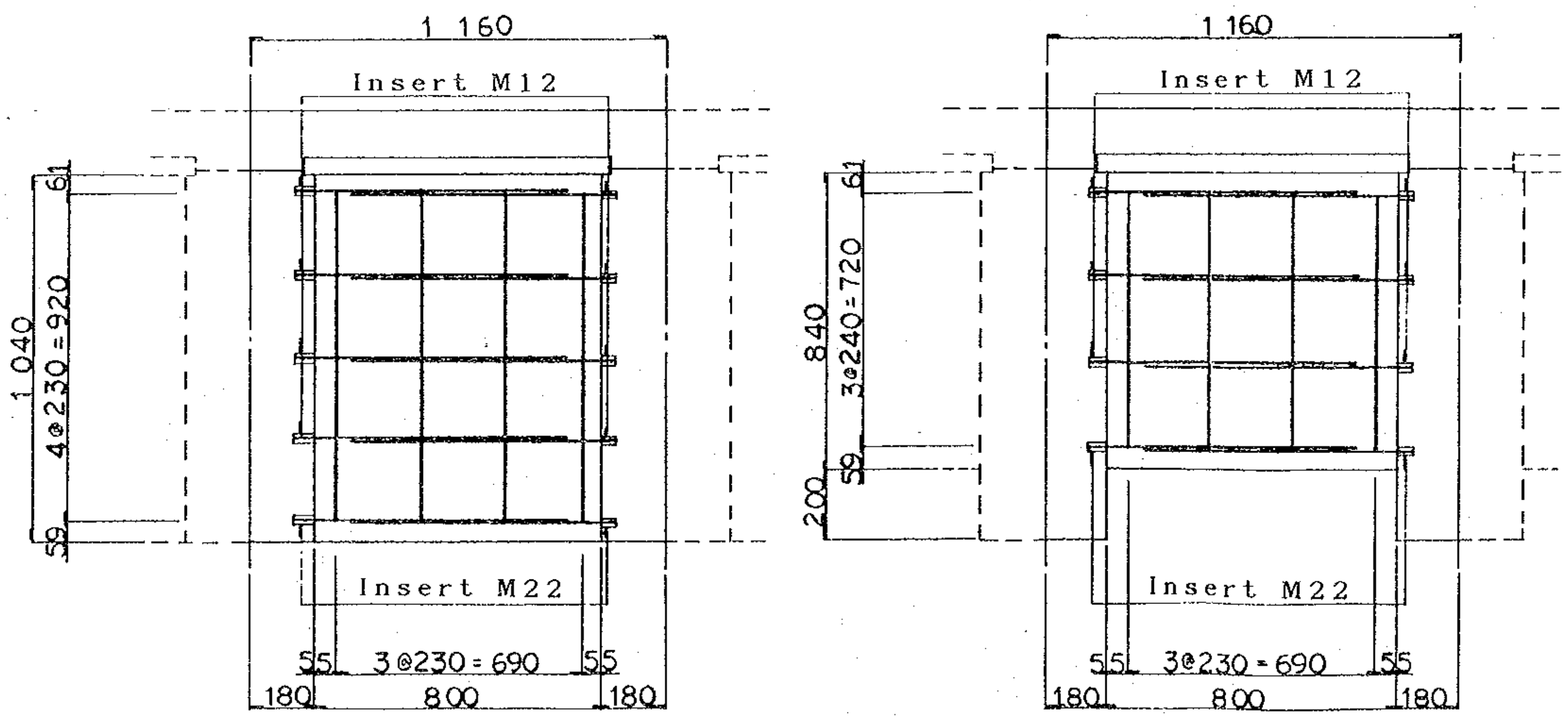


Profile



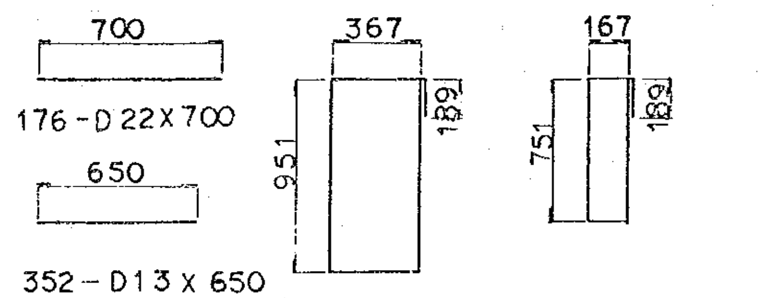

End

Section

Center

List of Quantity for Cross Beam (Per One Span)

| Item | Standard | Dimension | Quantity |
|---|---|---|---|
| Concrete | $\sigma_{28}=300$ | m³ | 7.3 |
| Form | | m² | 44.7 |
| Steel bar | Deformed Bar SD 295A | kg | 847.0 |
| Insert | M22 l=150 | no. | 176 |
| Insert | M12 l=100 | no. | 352 |




Bar Arrangement

**Fig. 9.16 Reinforcement of Cross Beam for Bridge No. 7 and No. 9 in Detail**

(2) Methods of Repairs

Cracks in the concrete, corrosion of reinforcing bars, and neutralizing of the concrete can be repaired by the following methods.

① Pressure injection method.
② Coating with cement concrete or mortar.
③ Coating with anti-neutralizing agent.

(3) Repair by Reinforcement

The following methods can be used to reinforce the concrete.

① Reinforcing steel plates can be added with expansion bolts or epoxy adhesive.
② Restricting weight of vehicles, or controlling bridge traffic.

2) Bridge No. 3 (Wadi Al Jizi Bat-7/105-15)

The concrete of this bridge is in an advanced stage of being neutralized, and is no longer waterproof. Load tests show some rigidity ($f = 1.07 > 1.0$) but it is not too strong. This can be attributed to the cracks in the main girder. The bridge is located on National Road Route No. 7 where there is heavy traffic of heavy vehicles. This tendency is expected to continue in the future.

(1) Cracks in the Concrete

① There are cracks (less than 0.2 mm to more than 0.2 mm) due to the bending of the main girder, and some cracks extend through the girder.
② There are cracks on the lower face of the cross beams and concrete slab (less than 0.2 mm to more than 0.2 mm).

(2) Some of the bridge footings are exposed due to scouring action.

(3) Protection of the Bridges by Repair

Repair of cracks in the concrete and neutralization can be performed as follows:

① Pressure injection

② Application of anti-neutralizing agent

(4) Strengthening of Bridges

The bridges can be strengthened by the following methods.

① Method of Increasing Cross Sectional Area of Members:

- Add new concrete covering to the reinforced concrete (Fig. 9.17).

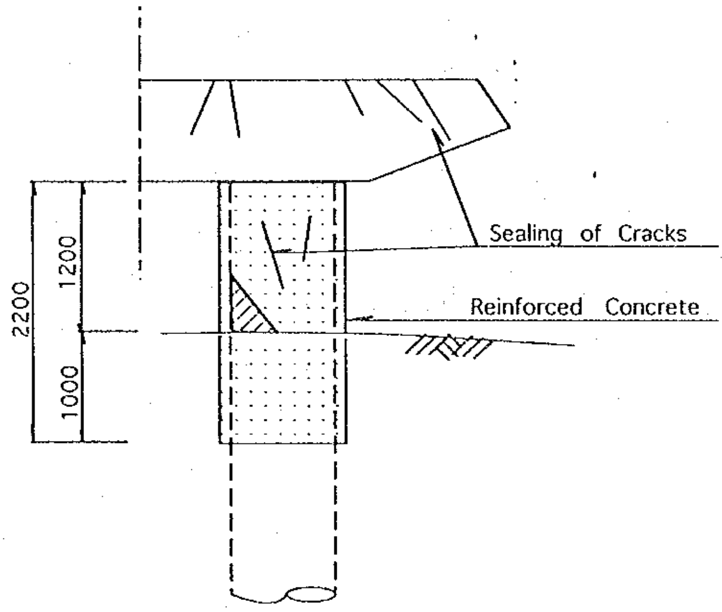



**Fig. 9.17 Strengthening of Pier**

② Adding Reinforcing Steel Plates

3) Bridge No. 6 (Rusail-Nizwa Dak-15/100-01)

The concrete in this bridge is neutralized and has lost its waterproofing capabilities.

(1) The rubber bearings are disfigured and should be inspected periodically.

(2) Repair Method

① Replace the rubber bearing.

4) Bridge No. 8 (Buraimi/Ibri/Nizwa Dak-21/600-01)

The concrete in this bridge has a large water absorbing rate and is not watertight. Load tests indicate lack of rigidity ($f = 0.94 < 1.0$) and this can be attributed to the cracks in the main girder. The bridge is located on National Road Route 21 where there is dense traffic of heavy vehicles (48.4 ton), and this trend is expected to increase in the future.

(1) Cracks in the Concrete

① There are many cracks in the main girder (less than 0.2 mm to more than 0.2 mm), and there are some that extend through the girder.

② The substructure is damaged from the flow of rock and mud.

(2) The substructure is damaged from the flow of stones and mud.

(3) Repair Methods

The following methods are suggested to repair cracks in the concrete and neutralizing.

① Pressure injection

② Coating method

(4) Strengthening Methods

The following strengthening methods are proposed.

① Increase Cross Section of Member:

- Increase strength of bridge piers by adding concrete. Drive H-beams around bridge footings and protect from scouring action.

② Restrict loads on bridges, regulate traffic.

## 9.3 Register of Existing Bridges

A good bridge register is important for the operation and maintenance of the existing bridges, and will provide the basic data for future planning, and as source of records and a lifelong record of the bridges.

A check of the existing bridge records was made, and a register in addition to filing of the drawings. It is recommended that they keep record of the following bridge inspection records.

(1) Bridge specifications and design standards
(2) Design load information
(3) The materials used and allowable stresses
(4) Year of design
(5) Name of company performing design
(6) Year construction completed
(7) Name of company performing construction work

The date bridge inspection was performed and the nine bridges inspected were as follows:

| | |
|---|---|
| Bridge No. 1: | Bat-1/308-02 |
| Bridge No. 2: | Bat-7/102-02 |
| Bridge No. 3: | Bat-7/105-15 |
| Bridge No. 4: | Bat-7/202-27 |
| Bridge No. 5: | Bat-13/200-01 |
| Bridge No. 6: | Dak-15/100-01 |
| Bridge No. 7: | Dak-23/100-02 |
| Bridge No. 8: | Dak-23/100-02 |
| Bridge No. 9: | Srq-23/600-12 |

**Bridge No. 1: BRIDGE INVENTORY**

| | | | | | |
|---|---|---|---|---|---|
| | | | | REFERENCE NO. | |
| BRIDGE NAME | BAT-1/308-02 | ROAD NAME | BATINAH COASTAL HIGHWAY | WORK CENTER | Sohar |
| REGION | from: Al Batinah | CHAINAGE | from: | INVENTORY DATE | |
| | to : | | to : | DRAWING NO. | |

| | | |
|---|---|---|
| SUPERSTRUCTURE | Bridge Type | Simple Rectangular R/C Girder Bridge |
| | Bridge Length (m) | 90.00 |
| | Span | Length (m): 6 x 15.00 |
| | | Number : 6 |
| | Road Width (m) | 9.00 |
| | Side Walks (m) | 2 x 0.50 |
| | Median (m) | — |
| | Traffic Lanes | 2 |
| | Alignment | Skew θ° : — |
| | | Curved R(A): — m |
| | Girder | Type : Precast R/C |
| | | Depth : 1.13 m |
| | | Number : 4 |
| | | Space : 2.85 m |
| | Pavement | Type : Asphalt |
| | | Thick (cm) : 5.0 |
| | Slab | Type : Reinforced Concrete |
| | | Thick (cm) : 17.0 |
| | Curb | Width (m) 0.75 x Height (m) 0.20 |
| | Handrail | Type: Parapet Wall/Metal Handrail |
| | | Height (m) : 1.27 |
| | Expansion Joint | Rubber Joint |
| | Shoe | Rubber Bearing |
| | Appendix | |

| | | |
|---|---|---|
| SUBSTRUCTURE | Abutment | Type: Retaining with Constant Thickness |
| | | Height (m) 3.50 x Length (m) 10.50 |
| | Pier | Type: Capped with Multiple Columns |
| | | Head Width (m): 1.15 x 1.05 Depth |
| | | Height (m) 4.20 x Length (m) 10.45 |
| | Pier Column | Section : Circular |
| | | Dimension (m): ø1.00 |
| | | Space (m) : 5.80 |
| DESIGN | Specification | |
| | Live Load | |
| | Concrete | $\sigma_{ck}$ : kgf/cm$^2$ |
| | Reinforcement | $\sigma_{ta}$ : kgf/cm$^2$ |
| | Prestressed Force | T : ton |
| | PC Material | |
| | Appendix Load | |
| | Special Load & Others | |
| | Seismic Coefficient | Kv = ± KH : |
| | Consultant | |
| | Design Date | |
| CON-STRUC-TION | Contractor | |
| | Construction Date | |
| COST | Superstructure | |
| | Substructure | |
| REMARKS | Traffic Control if any: | Load Limit: T = ton |

**Bridge No. 2: BRIDGE INVENTORY**

| | | | | | |
|---|---|---|---|---|---|
| BRIDGE NAME | BAT-7/102-02 | ROAD NAME | WADI AL JIZI | REFERENCE NO. | |
| | | | | WORK CENTER | Sohar |
| REGION | from: Al Batinah | CHAINAGE | from: | INVENTORY DATE | |
| | to : | | to : | DRAWING NO. | |

| | | | | | |
|---|---|---|---|---|---|
| SUPERSTRUCTURE | Bridge Type | Simple Rectangular R/C Girder Bridge | SUBSTRUCTURE | Abutment | Type: Retaining with Constant |
| | Bridge Length (m) | 76.00 | | | Height (m) 4.00 x Length (m) 10.14 |
| | Span | Length (m): 8.0 + 4 x 15.0 + 8.0 | | Pier | Type: Solid Panel - Rectangular Shape |
| | | Number : 6 | | | Head Width (m): 1.00 |
| | Road Width (m) | 8.60 | | | Height (m) 3.40 x Length (m) 9.47 |
| | Side Walks (m) | 2 x 0.52 | | Pier Column | Section : |
| | Median (m) | — | | | Dimension (m): |
| | Traffic Lanes | 2 | | | Space (m) : |
| | Alignment | Skew θ° : — | DESIGN | Specification | AASHTO |
| | | Curved R(A): — m | | Live Load | HS20-44 32 t |
| | Girder | Type : Precast R/C | | Concrete | $\sigma_{ck}$ : kgf/cm$^2$ |
| | | Depth : 1.13 m | | Reinforcement | $\sigma_{ta}$ : kgf/cm$^2$ |
| | | Number : 4 | | Prestressed Force | T : ton |
| | | Space : 2.70 m | | PC Material | |
| | Pavement | Type : Asphalt | | Appendix Load | |
| | | Thick (cm) : 5.0 | | Special Load & Others | |
| | Slab | Type : Reinforced Concrete | | Seismic Coefficient | Kv = ± KH : |
| | | Thick (cm) : 17.0 | | Consultant | Consult Ltd. |
| | Curb | Width (m) 0.77 x Height (m) 0.25 | | Design Date | |
| | Handrail | Type: Parapet Wall/Metal Handrail | CON-STRUC-TION | Contractor | Strabag |
| | | Height (m) : 1.00 | | Construction Date | 1975 - 1977 |
| | Expansion Joint | Rubber Joint | COST | Superstructure | |
| | Shoe | Rubber Bearing | | Substructure | |
| | Appendix | | REMARKS | Traffic Control if any: | Load Limit: T = ton |

**Bridge No. 3: BRIDGE INVENTORY**

| | | | | | |
|---|---|---|---|---|---|
| | | | | REFERENCE NO. | |
| BRIDGE NAME | BAT-7/105-15 | ROAD NAME | WADI AL JIZI | WORK CENTER | Sohar |
| REGION | from: Al Batinah | CHAINAGE | from: | INVENTORY DATE | |
| | to : | | to : | DRAWING NO. | |

| | | |
|---|---|---|
| SUPERSTRUCTURE | Bridge Type | Simple Rectangular R/C Girder Bridge |
| | Bridge Length (m) | 211.00 |
| | Span | Length (m): 8.0 + 13 x 15.0 + 8.0 |
| | | Number : 15 |
| | Road Width (m) | 8.60 |
| | Side Walks (m) | 2 x 0.50 |
| | Median (m) | — |
| | Traffic Lanes | 2 |
| | Alignment | Skew θ° : — |
| | | Curved R(A): — m |
| | Girder | Type : Precast R/C |
| | | Depth : 1.13 m |
| | | Number : 4 |
| | | Space : 2.70 m |
| | Pavement | Type : Asphalt |
| | | Thick (cm) : 5.0 |
| | Slab | Type : Reinforced Concrete |
| | | Thick (cm) : 17.0 |
| | Curb | Width (m) 0.75 x Height (m) 0.25 |
| | Handrail | Type: Parapet Wall/Metal Handrail |
| | | Height (m) : 1.00 |
| | Expansion Joint | Rubber Joint |
| | Shoe | Rubber Bearing |
| | Appendix | |

| | | |
|---|---|---|
| SUBSTRUCTURE | Abutment | Type: Retaining with Constant |
| | | Height (m) 9.20 x Length (m) 10.10 |
| | Pier | Type: Capped with Multiple Column |
| | | Head Width (m): 1.07 x 1.07 Depth |
| | | Height (m) 10.64 x Length (m) 9.40 |
| | Pier Column | Section : Circular |
| | | Dimension (m): ø0.90 |
| | | Space (m) : 4.60 |
| DESIGN | Specification | AASHTO |
| | Live Load | HS20-44 32 t |
| | Concrete | $\sigma_{ck}$ : kgf/cm$^2$ |
| | Reinforcement | $\sigma_{ta}$ : kgf/cm$^2$ |
| | Prestressed Force | T : ton |
| | PC Material | |
| | Appendix Load | |
| | Special Load & Others | |
| | Seismic Coefficient | Kv = ± KH : |
| | Consultant | Consult Ltd. |
| | Design Date | |
| CON-STRUC-TION | Contractor | Strabag |
| | Construction Date | 1975 - 1977 |
| COST | Superstructure | |
| | Substructure | |
| REMARKS | Traffic Control if any: | Load Limit: T = ton |

**Bridge No. 4: BRIDGE INVENTORY**

| | | | | | |
|---|---|---|---|---|---|
| | | | | REFERENCE NO. | |
| BRIDGE NAME | DAH-7/202-27 | ROAD NAME | WADI AL JIZI | WORK CENTER | Al Buraimi |
| REGION | from: A'Dhahira | CHAINAGE | from: | INVENTORY DATE | |
| | to : | | to : | DRAWING NO. | |

| | | | | | |
|---|---|---|---|---|---|
| SUPERSTRUCTURE | Bridge Type | Simple Rectangular R/C Girder Bridge | SUBSTRUCTURE | Abutment | Type: Retaining with Constant |
| | Bridge Length (m) | 76.00 | | | Height (m) 4.00 x Length (m) 10.10 |
| | Span | Length (m): 8.0 + 4 x 15.0 + 8.0 | | Pier | Type: Solid Panel - Rectangular |
| | | Number : 6 | | | Head Width (m): 1.00 |
| | Road Width (m) | 8.60 | | | Height (m) 4.17 x Length (m) 9.65 |
| | Side Walks (m) | 2 x 0.50 | | Pier Column | Section : |
| | Median (m) | — | | | Dimension (m): |
| | Traffic Lanes | 2 | | | Space (m) : |
| | Alignment | Skew θ° : — | DESIGN | Specification | AASHTO |
| | | Curved R(A): 4000 m | | Live Load | HS20-44 32 t |
| | Girder | Type : Precast R/C | | Concrete | $\sigma_{ck}$ : kgf/cm$^2$ |
| | | Depth : 1.13 m | | Reinforcement | $\sigma_{ta}$ : kgf/cm$^2$ |
| | | Number : 4 | | Prestressed Force | T : ton |
| | | Space : 2.70 m | | PC Material | |
| | Pavement | Type : Asphalt | | Appendix Load | |
| | | Thick (cm) : 5.0 | | Special Load & Others | |
| | Slab | Type : Reinforced Concrete | | Seismic Coefficient | Kv = ± KH : |
| | | Thick (cm) : 17.0 | | Consultant | Consult Ltd. |
| | Curb | Width (m) 0.75 x Height (m) 0.25 | | Design Date | |
| | Handrail | Type: Parapet Wall/Metal Handrail | CON-STRUC-TION | Contractor | |
| | | Height (m) : 1.00 | | Construction Date | 1975 - 1977 |
| | Expansion Joint | Rubber Joint | COST | Superstructure | |
| | Shoe | Rubber Bearing | | Substructure | |
| | Appendix | | REMARKS | Traffic Control if any: | Load Limit: T = ton |

**Bridge No. 5: BRIDGE INVENTORY**

| | | | | |
|---|---|---|---|---|
| BRIDGE NAME | BAT-13/200-01 | ROAD NAME | BARKA - RUSTAQ | |
| | | | REFERENCE NO. | |
| | | | WORK CENTER | A'Rustaq |
| REGION | from: Al Batinah | CHAINAGE | from: | |
| | to : | | to : | |
| | | | INVENTORY DATE | |
| | | | DRAWING NO. | |

| | | | | | |
|---|---|---|---|---|---|
| SUPERSTRUCTURE | Bridge Type | Simple Rectangular R/C Girder Bridge | SUBSTRUCTURE | Abutment | Type: Retaining with Constant |
| | Bridge Length (m) | 105.00 | | | Height (m) 5.90 x Length (m) 10.10 |
| | Span | Length (m): 7 x 15.00 | | Pier | Type: Capped with Multiple Column |
| | | Number : 7 | | | Head Width (m): 1.07 x 1.07 Depth |
| | Road Width (m) | 8.00 | | | Height (m) 8.00 x Length (m) 9.40 |
| | Side Walks (m) | 2 x 0.80 | | Pier Column | Section : Circular |
| | Median (m) | — | | | Dimension (m): ø0.90 |
| | Traffic Lanes | 2 | | | Space (m) : 4.60 |
| | Alignment | Skew θ° : — | DESIGN | Specification | |
| | | Curved R(A): — m | | Live Load | |
| | Girder | Type : Precast R/C | | Concrete | σck : kgf/cm$^2$ |
| | | Depth : 1.13 m | | Reinforcement | σta : kgf/cm$^2$ |
| | | Number : 4 | | Prestressed Force | T : ton |
| | | Space : 2.70 m | | PC Material | |
| | Pavement | Type : Asphalt | | Appendix Load | |
| | | Thick (cm) : 5.0 | | Special Load & Others | |
| | Slab | Type : Reinforced Concrete | | Seismic Coefficient | Kv = ± KH : |
| | | Thick (cm) : 17.0 | | Consultant | Italconsult |
| | Curb | Width (m) 1.05 x Height (m) 0.25 | | Design Date | |
| | Handrail | Type: Parapet Wall/Metal Handrail | CON-STRUC-TION | Contractor | |
| | | Height (m) : 1.00 | | Construction Date | 1975 - 1977 |
| | Expansion Joint | Rubber Joint | COST | Superstructure | |
| | Shoe | Rubber Bearing | | Substructure | |
| | Appendix | | REMARKS | Traffic Control if any: | Load Limit: T = ton |

**Bridge No. 6: BRIDGE INVENTORY**

| | | | | | |
|---|---|---|---|---|---|
| BRIDGE NAME | DAK-15/100-01 | ROAD NAME | RUSAIL - NIZWA | REFERENCE NO. | |
| REGION | from: A'Dakhliya | CHAINAGE | from: | WORK CENTER | Samail |
| | to : | | to : | INVENTORY DATE | |
| | | | | DRAWING NO. | |

| | | | | | |
|---|---|---|---|---|---|
| SUPERSTRUCTURE | Bridge Type | Simple Rectangular P/C Girder Bridge | SUBSTRUCTURE | Abutment | Type: Spillway Abutment |
| | Bridge Length (m) | 180.00 | | | Height (m) 16.36 x Length (m) 10.10 |
| | Span | Length (m): 6 x 30.00 | | Pier | Type: Capped with Multiple Column |
| | | Number : 6 | | | Head Width (m): 2.5 x (1.25~1.85) Depth |
| | Road Width (m) | 7.70 | | | Height (m) 15.00 x Length (m) 10.90 |
| | Side Walks (m) | 2 x 0.85 | | Pier Column | Section : Circular |
| | Median (m) | — | | | Dimension (m): ø0.80 |
| | Traffic Lanes | 2 | | | Space (m) : 2.10 |
| | Alignment | Skew θ° : — | DESIGN | Specification | British |
| | | Curved R(A): 470 m | | Live Load | 45 HB |
| | Girder | Type : P/C | | Concrete | $\sigma_{ck}$ : kgf/cm² |
| | | Depth : 1.85 m | | Reinforcement | $\sigma_{ta}$ : kgf/cm² |
| | | Number : 5 | | Prestressed Force | T : ton |
| | | Space : 2.10 m | | PC Material | |
| | Pavement | Type : Asphalt | | Appendix Load | |
| | | Thick (cm) : 5.0 | | Special Load & Others | |
| | Slab | Type : Reinforced Concrete | | Seismic Coefficient | Kv = ± KH : |
| | | Thick (cm) : 18.0 | | Consultant | Gibb Petermuller |
| | Curb | Width (m) 1.20 x Height (m) 0.20 | | Design Date | |
| | Handrail | Type: I-Open Metal Railing | CON-STRUC-TION | Contractor | Strabag |
| | | Height (m) : 1.00 | | Construction Date | |
| | Expansion Joint | Rubber Joint | COST | Superstructure | |
| | Shoe | Rubber Bearing | | Substructure | |
| | Appendix | | REMARKS | Traffic Control if any: | Load Limit: T = ton |

**Bridge No. 7: BRIDGE INVENTORY**

| | | | | | |
|---|---|---|---|---|---|
| BRIDGE NAME | DAK-23/100-2 | ROAD NAME | BID BID - SUR | REFERENCE NO. | |
| | | | | WORK CENTER | Samail |
| REGION | from: A'Dakhliya | CHAINAGE | from: | INVENTORY DATE | |
| | to : | | to : | DRAWING NO. | |

| | | | | | |
|---|---|---|---|---|---|
| SUPERSTRUCTURE | Bridge Type | Simple Rectangular P/C Girder Bridge | SUBSTRUCTURE | Abutment | Type: Spillway Abutment |
| | Bridge Length (m) | 146.90 | | | Height (m) 7.44 x Length (m) 10.28 |
| | Span | Length (m): 20.95 + 5 x 21.00 + 20.95 | | Pier | Type: Capped with Multiple Column |
| | | Number : 7 | | | Head Width (m): 1.8 x (1.12~1.0) Depth |
| | Road Width (m) | 7.50 | | | Height (m) 11.00 x Length (m) 10.00 |
| | Side Walks (m) | 2 x 1.15 | | Pier Column | Section : Circular |
| | Median (m) | — | | | Dimension (m): ø1.20 |
| | Traffic Lanes | 2 | | | Space (m) : 5.00 |
| | Alignment | Skew θ° : — | DESIGN | Specification | French |
| | | Curved R(A): — m | | Live Load | BC 30 t |
| | Girder | Type : P/C | | Concrete | $\sigma_{ck}$ : kgf/cm$^2$ |
| | | Depth : 1.05 m | | Reinforcement | $\sigma_{ta}$ : kgf/cm$^2$ |
| | | Number : 9 | | Prestressed Force | T : ton |
| | | Space : 1.16 m | | PC Material | |
| | Pavement | Type : Asphalt | | Appendix Load | |
| | | Thick (cm) : 5.0 | | Special Load & Others | |
| | Slab | Type : R/C on Precast Block | | Seismic Coefficient | Kv = ± KH : |
| | | Thick (cm) : 17.0 | | Consultant | Sauti Renardet |
| | Curb | Width (m) 1.68 x Height (m) 0.20 | | Design Date | |
| | Handrail | Type: Open Metal Railing | CON-STRUC-TION | Contractor | Dumez |
| | | Height (m) : 1.00 | | Construction Date | 1975 - 1977 |
| | Expansion Joint | Rubber Joint | COST | Superstructure | |
| | Shoe | Rubber Bearing | | Substructure | |
| | Appendix | | REMARKS | Traffic Control if any: | Load Limit: T = ton |

**Bridge No. 8: BRIDGE INVENTORY**

| | | | | | |
|---|---|---|---|---|---|
| | | | | REFERENCE NO. | |
| BRIDGE NAME | DAK-21/600-01 | ROAD NAME | BURAIMI/IBRI/NIZWA | WORK CENTER | Bahla |
| REGION | from: A'Dakhliya | CHAINAGE | from: | INVENTORY DATE | |
| | to : | | to : | DRAWING NO. | |

| | | | | | |
|---|---|---|---|---|---|
| SUPERSTRUCTURE | Bridge Type | Simple Rectangular R/C Girder Bridge | SUBSTRUCTURE | Abutment | Type: Retaining with Constant |
| | Bridge Length (m) | 135.00 | | | Height (m) 8.07 x Length (m) 10.10 |
| | Span | Length (m): 9 x 15.00 | | Pier | Type: Capped with Multiple Column |
| | | Number : 9 | | | Head Width (m): 1.07 x 1.07 Depth |
| | Road Width (m) | 8.00 | | | Height (m) 7.54 x Length (m) 9.40 |
| | Side Walks (m) | 0.775 + 0.825 | | Pier Column | Section : Circular |
| | Median (m) | — | | | Dimension (m): ø0.90 |
| | Traffic Lanes | 2 | | | Space (m) : 4.60 |
| | Alignment | Skew θ° : — | DESIGN | Specification | British |
| | | Curved R(A): 575 m | | Live Load | 45 HB |
| | Girder | Type : Precast R/C | | Concrete | $\sigma_{ck}$ : kgf/cm$^2$ |
| | | Depth : 1.13 m | | Reinforcement | $\sigma_{ta}$ : kgf/cm$^2$ |
| | | Number : 4 | | Prestressed Force | T : ton |
| | | Space : 2.70 m | | PC Material | |
| | Pavement | Type : Asphalt | | Appendix Load | |
| | | Thick (cm) : 5.0 | | Special Load & Others | |
| | Slab | Type : Reinforced Concrete | | Seismic Coefficient | Kv = ± KH : |
| | | Thick (cm) : 17 | | Consultant | Gibb Petermuller |
| | Curb | Width (m) 1.025 (1.075) x Height (m) 0.25 | | Design Date | |
| | Handrail | Type: Parapet Wall/Metal Handrail | CON-STRUC TION | Contractor | Strabag |
| | | Height (m) : 1.0 | | Construction Date | |
| | Expansion Joint | Rubber Joint | COST | Superstructure | |
| | Shoe | Rubber Bearing | | Substructure | |
| | Appendix | | REMARKS | Traffic Control if any: | Load Limit: T = ton |

**Bridge No. 9: BRIDGE INVENTORY**

| | | | | | |
|---|---|---|---|---|---|
| | | | | REFERENCE NO. | |
| BRIDGE NAME | SRQ-23/600-12 | ROAD NAME | BID BID - SUR | WORK CENTER | Al Kamil |
| REGION | from: A'Sharqiya | CHAINAGE | from: | INVENTORY DATE | |
| | to : | | to : | DRAWING NO. | |

| | | |
|---|---|---|
| SUPERSTRUCTURE | Bridge Type | Simple Rectangular P/C Girder Bridge |
| | Bridge Length (m) | 146.90 |
| | Span | Length (m): 20.95 + 5 x 21.0 + 20.95 |
| | | Number : 7 |
| | Road Width (m) | 7.50 |
| | Side Walks (m) | 2 x 1.15 |
| | Median (m) | — |
| | Traffic Lanes | 2 |
| | Alignment | Skew θ° : — |
| | | Curved R(A): — m |
| | Girder | Type : P/C |
| | | Depth : 1.05 m |
| | | Number : 9 |
| | | Space : 1.16 m |
| | Pavement | Type : Asphalt |
| | | Thick (cm) : 5.0 |
| | Slab | Type : R/C on Precast Block |
| | | Thick (cm) : 17 |
| | Curb | Width (m) 1.68 x Height (m) 0.20 |
| | Handrail | Type: Open Metal Railing |
| | | Height (m) : 1.00 |
| | Expansion Joint | Rubber Joint |
| | Shoe | Rubber Bearing |
| | Appendix | |

| | | |
|---|---|---|
| SUBSTRUCTURE | Abutment | Type: Bank Seat Abutment |
| | | Height (m) 5.92 x Length (m) 10.30 |
| | Pier | Type: Capped with Multiple Column |
| | | Head Width (m): 1.8 x (1.2~1.0) Depth |
| | | Height (m) 10.96 x Length (m) 10.00 |
| | Pier Column | Section : Circular |
| | | Dimension (m): ø1.20 |
| | | Space (m) : 5.00 |
| DESIGN | Specification | French |
| | Live Load | BC 30 t |
| | Concrete | $\sigma_{ck}$ : kgf/cm² |
| | Reinforcement | $\sigma_{ta}$ : kgf/cm² |
| | Prestressed Force | T : ton |
| | PC Material | |
| | Appendix Load | |
| | Special Load & Others | |
| | Seismic Coefficient | Kv = ± KH : |
| | Consultant | Sauti Renardet |
| | Design Date | |
| CON-STRUCTION | Contractor | |
| | Construction Date | |
| COST | Superstructure | |
| | Substructure | |
| REMARKS | Traffic Control if any: | Load Limit: T = ton |

# CHAPTER 10 MAINTENANCE MANAGEMENT PLAN

# CHAPTER 10

# MAINTENANCE MANAGEMENT PLAN

Maintenance of all structures will start from the time of completion of construction and beginning of operation.

To maintain a structure in sound condition constantly, it is important to take a countermeasure in advance when found in abnormal condition under inspection. Therefore, maintenance management is one of the most important works for safety in transport, economic growth and preservation of road structure.

At present, there are fifty-eight bridges under the control of the Directorate General of Roads (DGR). Most of the road bridges were completed from 1975 to 1982. Design, construction method and materials were conforming to the AASHTO, British Standard and French Standard, and therefore their soundness and bearing capacity of bridges are not uniformed. All these bridges have been in service more than twenty years, and some parts have suffered superannuation condition due to increase of traffic and size of the vehicles.

There are unsuitable bridges for existing traffic condition that may easily suffer damage.

To maintain the road structure, it is important to establish an inspection method, inspection items, judgment standard and maintenance management plan, and to operate the inspection efficiently. The accuracy of inspection results depend upon the skill of the inspector, affecting the countermeasure cost. Therefore, training of an inspector is a very important matter.

## 10.1 Organization

Organization of DGR has a maintenance department which consists of Road Maintenance and Equipment Maintenance, which are in charge of maintenance work.

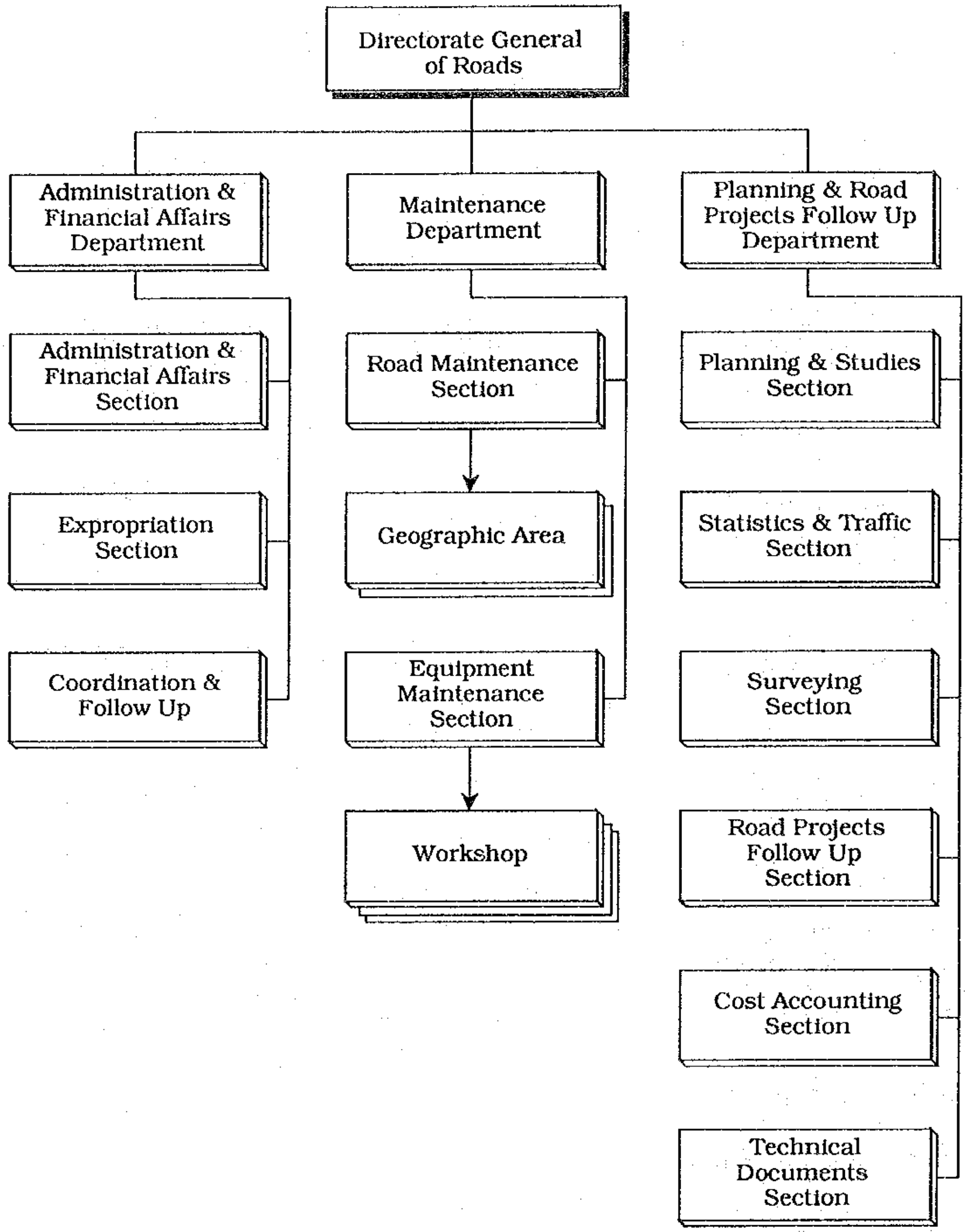



**Fig. 10.1 Organization of DGR**

## 10.2 Present Situation of Maintenance Management

At the maintenance department, computer management of road and bridge inventory, and maintenance works (inspection, examination and repair) are carried out. However, the filing of design drawings and documents is not sufficient.

These documents are most important data for maintenance after completion of the construction and therefore, these data should be filed with road and bridge inventory at the DGR Maintenance Department. The job of maintenance management is outlined and regulated in "The Maintenance Management System (MMS)" and is composed of the following items:

(1) Road Inventory Data
(2) Construction History Data
(3) Traffic Data
(4) Accident Data
(5) Road Data Base
(6) Periodic Inspection of Road Sections
(7) Specific Inspection and Testing of Identified Road Sections
(8) Prediction and Planning of Maintenance Works
(9) Budgeting for Maintenance Works
(10) Setting Priorities of Maintenance Works
(11) Specifications Monitoring and Training
(12) Implementation of the Specified Maintenance Works
(13) Cost Accounting

## 10.3 Planning of Maintenance Management

Maintenance management for structures is composed of the next three items.

- Routine maintenance
- The inspection for confirmation of effect to the structure from the routine maintenance report
- The repairing and countermeasure for damaged part judged from the inspection.

For the purpose of efficient maintenance management of inspection, examination and repairing, it is important to make the maintenance guideline and to file the data.

(1) Filing of Design Documents
(2) Preparation of Structure Inventory
(3) Preparation of Maintenance Inventory
(4) Establishment of Maintenance Guideline

## 10.4 Proposal of Bridge Inventory

For bridge maintenance, soundness of bridge should be grasped with design documents, bridge inventory and bridge maintenance inventory which have recorded inspection and repair data.

1) Bridge Inventory Contents
   (1) Bridge Name
   (2) Road Name
   (3) Chainage
   (4) Inventory of Superstructure
   (5) Inventory of Substructure
   (6) Design Standard and Specification
   (7) Design Load
   (8) Allowable Stress of Material
   (9) Design Date
   (10) Consultant
   (11) Construction Date
   (12) Contractor
   (13) Construction Cost
   (14) Workcenter

2) Bridge Maintenance Inventory
   (1) Bridge Name
   (2) Road Name
   (3) Chainage
   (4) Inspection Activity
   (5) Maintenance Activity
   (6) Workcenter

# BRIDGE INVENTORY

| | | | |
|---|---|---|---|
| REFERENCE NO. | | | |
| WORK CENTER | | | |
| INVENTORY DATE | | | |
| DRAWING NO. | | | |

| | | | |
|---|---|---|---|
| BRIDGE NAME | | ROAD NAME | |
| REGION | from : | CHAINAGE | from : |
| | to : | | to : |

| | | |
|---|---|---|
| SUPER STRUCTURE | Bridge Type | |
| | Bridge Length (m) | |
| | Span | Length (m) : |
| | | Number : |
| | Road Width (m) | |
| | Side Walks (m) | |
| | Median (m) | |
| | Traffic Lanes | |
| | ALIGNMENT | Skew θ° = |
| | | Curved R(A) = m |
| | GIRDER | Type : |
| | | Depth : |
| | | Number : |
| | | Space : |
| | PAVEMENT | Type : |
| | | Thick (cm) : |
| | SLAB | Type : |
| | | Thick (cm) : |
| | CURB | Width (m) x Height (m) |
| | HAND RAIL | Type : |
| | | Height (m) : |
| | EXPANSION JOINT | |
| | SHOE | |
| | Appendix | |
| SUB- | ABUTMENT | Type : |
| | | Height (m) x Length (m) |

| | | |
|---|---|---|
| SUB-STRUCTURE | PIER | Type : |
| | | Head Width (m): |
| | | Height (m) x Length (m) |
| | Pier Column | Section : |
| | | Dimension (m) : |
| | | Space (m) : |
| DESIGN | Specification | |
| | Live Load | |
| | Concrete | $\sigma_{ck}$ = kgf/cm$^2$ |
| | Reinforcement | $\sigma_{ta}$ = kgf/cm$^2$ |
| | Prestressed Force | T = ton |
| | P C Material | |
| | Appendix Load | |
| | Special Load & others | |
| | Seismic Coefficient | Kv = ± KH = |
| | Consultant | |
| | Design Date | |
| CONSTRUCTION | Contractor | |
| | Construction Date | |
| | | |
| COST | Super Structure | |
| | Sub Structure | |
| REMARKS | Traffic Control if any : Load Limit : T= ton | |
| | | |
| | | |
| | | |

# BRIDGE MAINTENANCE INVETORY

| | | | | | |
|---|---|---|---|---|---|
| BRIDGE NAME | | ROAD NAME | | REFERENCE NO. | |
| REGION | from : | CHAINAGE | from : | WORKCENTER | |
| | to : | | to : | INVENTORY DATE | |
| | | | | DRAWING NO. | |

**INSPECTION ACTIVITY**

| Record No. | Date | Activity | Inspector | Span No. | Member | Material | Type of Damage | Judgment | Counter measure | Description |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | |
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**MAINTENANCE ACTIVITY**

| Date | Span. No. | Member | Material | Counter measure |
|---|---|---|---|---|
| | | | | |
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## 10.5 Proposal for Check-up Guidelines

In order to insure that a bridge will always retain its soundness, it is necessary to discover and repair any areas of failure. In order to do this, a well-formulated check-up including all necessary check-up items must be decided upon to recognize the characteristics and deformation of the structure in question, and the results of the check-up must be documented.

① Conduct a survey which enables early discovery of deformity.
② Know whether or not the deformation is one of progressive nature.
③ Make supposition of when deformation began as soon as possible.
④ Judge from situation and position of deformation its cause and future progression, evaluate it and make specific plans for future check-ups.
⑤ Formulate effective methods of repair and/or reinforcement and conduct them.

(1) Types of Inspection

Inspection is carried out in five different methods, according to situation and purpose.

1) Routine Inspection

All bridges are included in the routine inspection, which is conducted in conjunction with the routine road inspection. This is for early discovery of any failure and is conducted as a solely visual inspection.

2) Recurrent Inspection

All bridges are included in the recurrent inspection, which is conducted at regular intervals to ensure overall safety. This is chiefly a visual inspection but includes the use of some simple instruments.

3) Emergency Inspection

An emergency inspection is necessary when any bridge has been in the area of an earthquake, a monsoon, heavy rains or other catastrophe; or if it is predicted to be so; or when an emergency situation has been discovered in the process of routine or regular inspection, a special check up is required to confirm the safety of the bridge in question.

4) Bridge Motion Observation

It is necessary to conduct motion observations in cases of areas of failure which are of a progressional nature, concentrating on the particular materials of a particular bridge. Such a survey would be carried out by visual observation and with some simple instruments on a regular basis.

5) Detailed Inspection

A detailed inspection is conducted on certain specified bridges chiefly with inspection instruments in order to judge the necessity of repair or reinforcement.

(2) Procedure of Inspection Management

Inspection management will be carried out in cooperation with examination and other related management.

Management procedures such as inspection, examination, countermeasure and observation are as shown in Figure 10.2 as below:

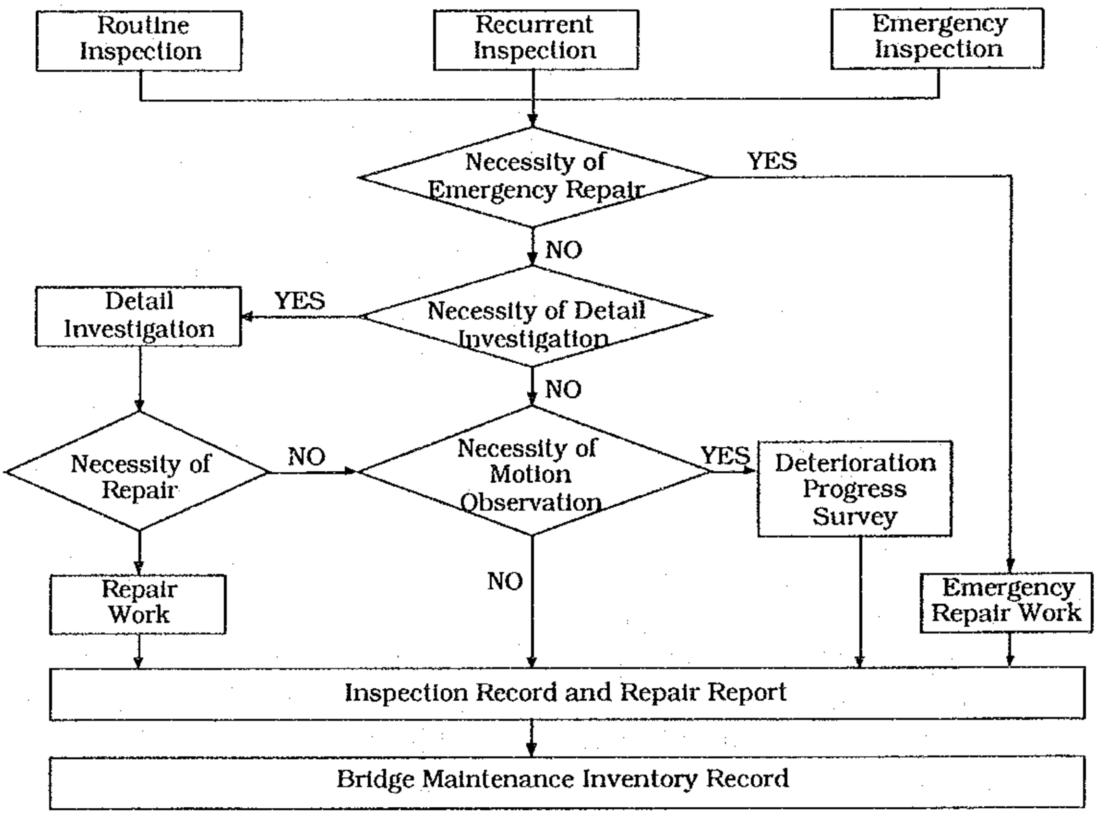



**Fig. 10.2 Inspection Procedure**

(3) Evaluation Standard

Judging the level of failure discovered in a routine, recurrent, or emergency check-up, an evaluation is assigned to each item of the overall structure; and emergency repair and/or method of repair is considered.

1) Routine Inspection

Routine inspection results are evaluated as follows:

**Table 10.1 Evaluation Standard of Routine Inspection**

| Rating | | Condition | Action Taken |
|---|---|---|---|
| I | Sound | Not Noticed | — |
| II | Fairly Unsound | Noticed | Recorded |
| III | Dangerous | Largely Noticed | Make Emergency Repairs |

2) Recurrent Inspection

Recurrent inspection results are evaluated as follows:

**Table 10.2 Evaluation Standard of Recurrent Inspection**

| Rating | | Condition | Action Taken |
|---|---|---|---|
| A | Sound | No damage noticed | — |
| B | Fairly Sound | Small damage noticed | Damage recorded |
| C | Fairly Unsound | Damage found | Conditions under observation |
| D | Not Safe | Large damages found | Make detailed bridge inspection |
| E | Dangerous | Large damage found. Could be harmful to the public | Make emergency repairs |

3) Emergency Inspection

Emergency inspection results are evaluated as follows:

**Table 10.3 Evaluation Standard of Emergency Inspection**

| Rating | | Damage | Action Taken |
|---|---|---|---|
| I | Sound | Not or Little Noticed | — |
| II | Fairly Unsound | Noticed | Conditions under Observation |
| III | Dangerous | Largely Noticed | Make Emergency Repairs |

(4) Inspection Frequency and Inspection Items

The combination of inspection frequency and inspection items are shown as follows:

**Table 10.4 The Combination of Inspection Frequency and Inspection Items**

| | | Daily Inspection | | Routine Inspection | Emergency Inspection |
|---|---|---|---|---|---|
| | | Routine Patrol | Recurrent Patrol | | |
| Inspection Method | | Visual Inspection by Patrol Car | Inspection by Foot | Scaffolding or Inspection Car | According to Purpose |
| Frequency | | On Occasion | 1 Time/ 3 Months | 1 Time/ 5 Years | According to Need |
| Objective Members | Super-structure | — | O | O | According to Purpose |
| | Slab | — | O | O | ditto |
| | Sub-structure | — | O | O | ditto |
| | Bearing | — | — | O | ditto |
| | Handrail | O | | O | ditto |
| | Curb | O | | O | ditto |
| | Surface Pavement | O | | O | ditto |
| | Joint | O | | O | ditto |
| | Drainage | O | | O | ditto |
| | Lighting System | O | | O | ditto |

(5) Survey Preparation

Prepare necessary equipment and personnel according to type of survey to be conducted. Survey is to be conducted by one with a certain amount of experience.

A standard surveying team would be as follows:

Team Composition

| | | |
|---|---|---|
| Routine Inspection : | 2 | 1 inspector, 1 assistant |
| Recurrent Inspection : | 3 | 1 inspector, 2 assistants |

(6) Making a Plan Sheet for Inspection

A plan sheet is necessary in preparing for an inspection. In making a plan sheet, the following items should be confirmed.

1) Construction standards, drafts
2) Type, sphere, and items of check-up
3) Schedule
4) Method
5) Inspecting staff and communications
6) Type and use of inspection equipment
7) Scaffolding equipment
8) Traffic control (during testing)
9) Records of past inspections
10) Method of report composition

(7) Inspection Equipment

Inspecting personnel need to bring a number of instruments to use in inspection, depending on the type of inspection to be conducted.

1) Inspection Equipment:

Test Hammer, Binoculars, Convex, Wirebrush, Crack Gauge, Nonius, Thread with weight

2) Recording Instruments:

Camera, Strobe, Film, Chalk, Blackboard, Felt tip pens, Paper

3) Auxiliary Equipment:

Ladder, Traffic control items, Rope, Packing tape, Flashlights, Safety belts, Inspection vehicle, Vehicle for testing

(8) Photographing

Photographing of check-up spots and filing the photographs are necessary for later reconfirmation.

① Photos are to be filed in conjunction with the report of the inspection survey.
② File according to work item.
③ Number photos and record date.
④ Add caption of explanation.

(9) Recording and Reporting Inspection Results

The written results of the check-up are recorded and filed along with drawings and photos of the damaged areas. Furthermore, damage which has been deemed dangerous as a result of inspection should be immediately reported to related ministry.

Check up results should consist of the following:

① Daily report
② Drawings of damaged areas
③ Photos of damaged areas

(10) Daily Inspection

Daily inspection will be carried out for the purpose of judgment of necessary countermeasures and/or repair, and to discover damage and/or abnormal conditions at early stage for keeping the bridge in sound condition.

1) Inspection Method

Daily inspection will be carried out during routine patrol and recurrent patrol for all bridges.

| | | |
|---|---|---|
| Routine Patrol | : | Visual inspection from patrol car for structure on the road |
| Recurrent Patrol | : | Visual inspection from approached point of bridge members |

2) Flow of Inspection

Flow of daily inspection is as Figure 10.3.

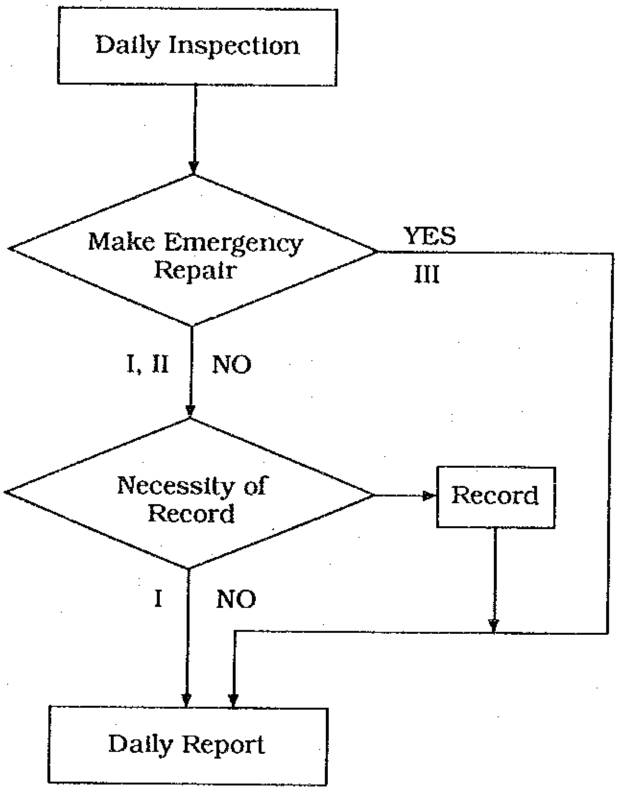



**Fig. 10.3 Flow of Daily Inspection**

3) Inspection Item

Inspection item is as shown in Table 10.5.

**Table 10.5 Daily Inspection Items**

| Members | | Routine Patrol | Recurrent Patrol |
|---|---|---|---|
| Super-structure | Main Beam | — | Vibration, Loss of Member |
| | Cross Beam | — | Loss of Member |
| | Slab | — | Come-off, Free lime |
| Sub-structure | Main Body | — | Loss of Member |
| | Foundation | — | Scouring |
| Handrail | Steel | Failure, Deformation | — |
| | Concrete | Loss of Member | — |
| Curb | Steel | Failure, Deformation | — |
| | Concrete | Loss of Member | — |
| Pavement | Asphalt | Pot Hole, Cracking Rutting Leakage | — |
| Drainage | | Leakage, Failure, Stuffed | — |
| Lighting | | Failure, Deformation | — |

4) Judgment Standard

Inspection result shall be judged from judgment standard, Table 10.6. Rank III bridge should be reported to maintenance office.

**Table 10.6 Judgment Standard of Daily Inspection**

| Rating | | Condition | Action Taken |
|---|---|---|---|
| I | Sound | No damage noticed | — |
| II | Fairly Unsound | Damage found | Recorded |
| III | Dangerous | Large damage found | Make Emergency Repairs |

5) Judgement Rank

Judgement rank is as shown Table 10.7.

**Table 10.7 Judgement Rank of Daily Inspection**

| Members | | Damage | Ranking | | |
|---|---|---|---|---|---|
| | | | I | II | III |
| Super-structure | Main Beam | Vibration | NONE | — | Present |
| | | Loss of Member | NONE | Present | Major |
| | Cross Beam | Loss of Member | NONE | Present | Major |
| | Slab | Come off | NONE | — | Present |
| | | Free lime | NONE | Present | — |
| Sub-structure | Main Body | Loss of Member | NONE | Present | Major |
| | Foundation | Scoring | NONE | Present | Major |
| Handrail | Steel | Failure | NONE | — | Present |
| | | Deformation | NONE | Present | Major |
| | Concrete | Loss of Member | NONE | Present | Major |
| Curb | Steel | Failure | NONE | — | Present |
| | | Deformation | NONE | Present | Major |
| | Concrete | Loss of Member | NONE | Present | Major |
| Pavement | Asphalt | Corrugation Difference | NONE | Present | Major |
| | | Pot Hole | NONE | Present | Major |
| | | Rutting | NONE | Present | Major |
| | | Leakage | NONE | Present | Major |
| Joint Rubber | | Failure | NONE | — | Present |
| | | Abnormal Opening | NONE | Present | Major |
| | | Deformation | NONE | Present | Major |
| | | Abnormal Sound | NONE | — | Present |
| | | Loss of Member | NONE | Present | Major |
| Drainage | | Leakage | NONE | Present | Major |
| | | Loss of Member | NONE | Present | Major |
| | | Stuffed | NONE | Present | Major |
| Lighting | | Failure | NONE | — | Present |
| | | Deformation | NONE | Present | Major |
| | | Loss of Member | NONE | Present | Major |

(11) Routine Inspection

Routine inspection is conducted on a regular basis, based on the long term inspection plan.

The purposes are to judge the soundness of ultimate strength and durability for structure, to detect the damage caused by malfunction in its early stages and to get the data for repair plan.

1) Inspection Flow

Inspection flow is as Figure 10.4.

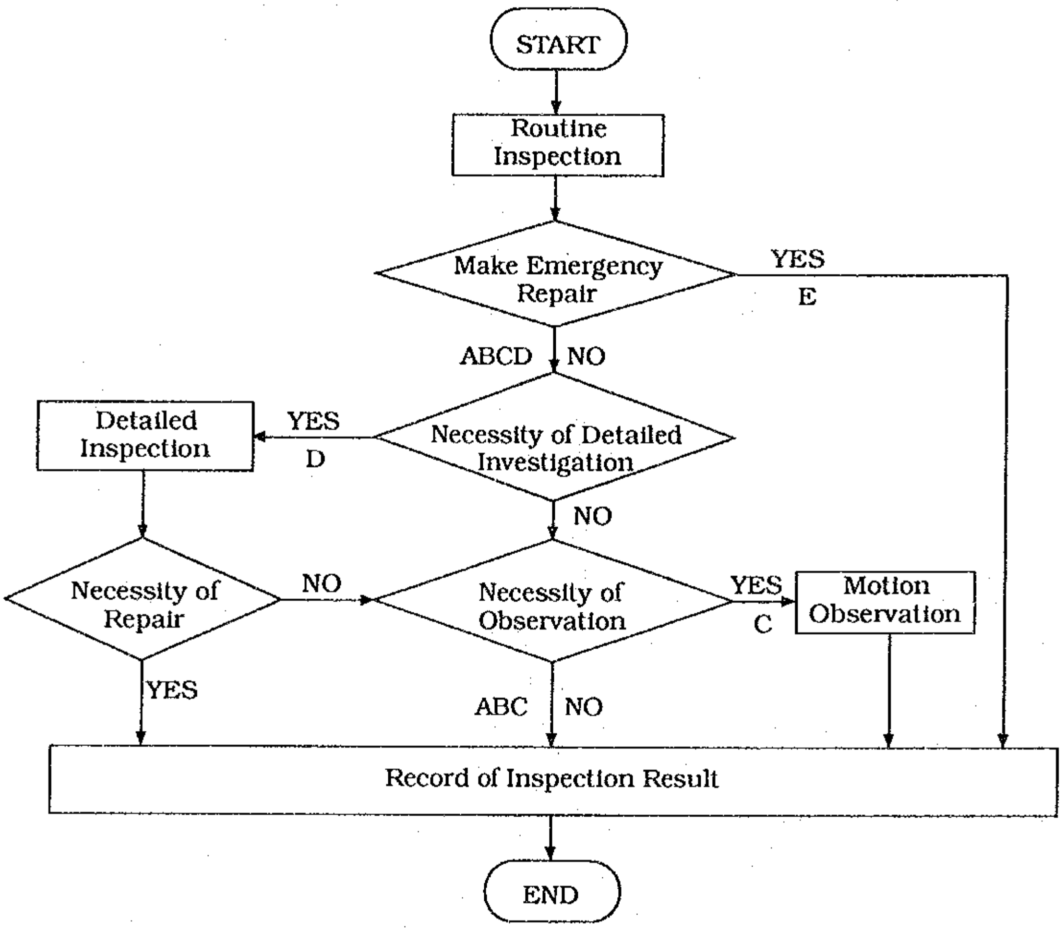



**Fig. 10.4 Inspection Flow**

2) Inspection Items

Inspection items are as listed Table 10.8.

**Table 10.8 Inspection Items**

| Members | | | Inspection Items |
|---|---|---|---|
| Super-structure | Concrete | Main Beam | Cracking, Scaling, Free Lime, Honeycombs, Corrosion Damage, Leakage, Vibration, Deflection, Loss of Member, Discoloration |
| | | Cross Beam Stringer | Cracking, Scaling, Free Lime, Honeycombs, Corrosion Damage, Leakage, Loss of Member, Discoloration |
| | | Slab | Cracking, Scaling, Honeycombs, Come-off, Damage of Joint, Corrosion Damage, Leakage |
| Sub-structure | Concrete | Abutment Pier | Cracking, Scaling, Corrosion Damage, Free Lime, Honeycombs, Wear, Discoloration, Leakage, Loss of Member |
| | Foundation | | Settlement, Movement, Inclination, Scour |
| Shoe | Steel Shoe | | Corrosion, Cracking, Loosen, Falling, Failure, Discoloration, Leakage, Deformation, Stuffed, Settlement, Movement, Inclination |
| | Rubber Shoe | | Discoloration, Leakage, Deformation, Stuffed, Loss of Member |
| | Mortar | | Cracking, Loss of Member |
| | Anchor Bolt | | Corrosion Damage, Cracking, Loosen, Falling, Failure, Deformation |
| Hand Rail | Steel | | Corrosion, Cracking, Loosen, Falling, Failure, Discoloration, Deformation |
| | Concrete | | Cracking, Scaling, Corrosion Damage, Free Lime, Honeycombs, Discoloration, Loss of Member |
| Curb | Steel | | Corrosion, Cracking, Loosen, Falling, Failure, Discoloration, Deformation |
| | Concrete | | Cracking, Scaling, Corrosion Damage, Free Lime, Honeycombs, Discoloration, Loss of Member |
| Pavement | Asphalt | | Pot Holes, Cracking, Rutting, Leakage |
| Expansion Joint | Steel | | Corrosion, Cracking, Loosen, Falling, Failure, Abnormal Opening, Abnormal Sound, Deformation |
| | Rubber | | Failure, Abnormal Opening, Abnormal Sound, Deformation, Loss of Member |
| | Concrete | | Cracking, Scaling, Exposure of Rebar, Loss of Member |
| Drainage | | | Corrosion, Cracking, Loosen, Falling, Failure, Discoloration, Leakage, Deformation, Loss of Member |
| Lighting | | | Corrosion, Cracking, Loosen, Falling, Failure, Discoloration, Leakage, Deformation, Loss of Member |
| Accessory | | | Corrosion, Cracking, Loosen, Falling, Failure, Deformation, Loss of Member |

3) Judgement Standard

Inspection result shall be judged from judgement standard as shown in Table 10.9.

E-ranked bridges should be reported to maintenance office.

**Table 10.9 Judgement Standard of Recurrent Inspection**

| Rating | | Condition | Action Taken |
|---|---|---|---|
| A | Sound | No damage noticed | — |
| B | Fairly Sound | Small damage noticed | Damage recorded |
| C | Fairly Unsound | Damage found | Conditions under observation |
| D | Not Safe | Large damages found | Make detailed bridge inspection |
| E | Dangerous | Large damages found. Could be harmful to the public | Make emergency repairs |

4) Judgement Ranking

Judgement ranking is as shown in Table 10.10.

**Table 10.10 Judgement Ranking of Recurrent Inspection (1)**

| Member | | | Damage | Damage Ranking | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | A | B | C | D | E |
| Super-structure | Con-crete | Main Beam | Cracking | NONE | – | Interval more than 50cm | Interval less than 50cm | Width Several Millimeter |
| Super-structure | Con-crete | Main Beam | Corrosion of Rebar Scaling | NONE | – | Exposed Rebar<br>Minor | Exposed Rebar<br>Minor | Loss of Rebar<br>Section |
| Super-structure | Con-crete | Main Beam | Free Lime | NONE | Present | – | – | – |
| Super-structure | Con-crete | Main Beam | Honeycombs | NONE | Minor | Major | – | – |
| Super-structure | Con-crete | Main Beam | Discoloration | NONE | Minor | | Major | – |
| Super-structure | Con-crete | Main Beam | Leakage | NONE | Present | – | – | – |
| Super-structure | Con-crete | Main Beam | Abnormal Vibration | NONE | – | – | Present | – |
| Super-structure | Con-crete | Main Beam | Abnormal Strain | NONE | – | – | Present | – |
| Super-structure | Con-crete | Main Beam | Loss of Member | NONE | – | Minor | – | Major |
| Super-structure | Con-crete | Cross Beam Stringer | Cracking | NONE | | Interval more than 50cm | Interval less than 50cm | Width Several Millimeter |
| Super-structure | Con-crete | Cross Beam Stringer | Corrosion of Rebar Scaling | NONE | – | Exposed Rebar<br>Minor | Exposed Rebar<br>Major | Loss of Rebar<br>Section |
| Super-structure | Con-crete | Cross Beam Stringer | Free Lime | NONE | Present | – | – | – |
| Super-structure | Con-crete | Cross Beam Stringer | Honeycombs | NONE | Minor | Major | – | – |
| Super-structure | Con-crete | Cross Beam Stringer | Discoloration | NONE | Minor | – | Major | – |
| Super-structure | Con-crete | Cross Beam Stringer | Leakage | NONE | Present | – | – | – |
| Super-structure | Con-crete | Cross Beam Stringer | Loss of Member | NONE | – | Minor | – | Major |
| Super-structure | Con-crete | Slab | Corrosion of Rebar Scaling | NONE | – | Exposed Rebar<br>Minor | Exposed Rebar<br>Major | Loss of Rebar<br>Section |
| Super-structure | Con-crete | Slab | Free Lime | NONE | Present | – | – | – |
| Super-structure | Con-crete | Slab | Honeycombs | NONE | Minor | Major | – | – |
| Super-structure | Con-crete | Slab | Falling | NONE | – | – | – | Present |
| Super-structure | Con-crete | Slab | Damage of Joint | NONE | – | Minor | – | Major |
| Super-structure | Con-crete | Slab | Cracking of Slab | NONE | Single Direction | Multiple Direction<br>Interval more than 50cm | Multiple Direction<br>Interval less than 50cm | Multiple Direction<br>with corrosion |
| Super-structure | Con-crete | Slab | Discoloration | NONE | Minor | – | Major | – |
| Super-structure | Con-crete | Slab | Leakage | NONE | Present | – | – | – |

**Table 10.10 Judgement Ranking of Recurrent Inspection (2)**

| Member | | | Damage | Damage Ranking | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | A | B | C | D | E |
| Sub-structure | Con-crete | Abut-ment Pier | Cracking | NONE | – | Interval more than 50cm | Interval less than 50cm | Width Several Millimeter |
| | | | Corrosion of Rebar Scaling | NONE | – | Exposed Rebar Minor | Exposed Rebar Major | Loss of Rebar Section |
| | | | Free Lime | NONE | Present | – | – | – |
| | | | Honeycombs | NONE | Minor | Major | – | – |
| | | | Scour | NONE | Minor | – | – | – |
| | | | Discoloration | NONE | Minor | – | Major | – |
| | | | Leakage | NONE | Present | – | – | – |
| | | | Loss of Member | NONE | – | Minor | – | Major |
| Shoe | Shoe | Rubber | Discoloration | NONE | Minor | – | Major | – |
| | | | Leakage | NONE | Present | – | – | – |
| | | | Deformation | NONE | – | Minor | – | Major |
| | | | Staffed | NONE | – | Minor | – | Major |
| | | | Loss of Member | NONE | – | Minor | – | Major |
| | Mortar | | Cracking | NONE | – | Interval more than 50cm | Interval less than 50cm | Width Several Millimeter |
| | | | Loss of Member | NONE | – | Minor | – | Major |
| | Anchor Bolt | | Corrosion | NONE | Surface Minor | Surface Major | Loss of Section Minor | Loss of Section Major |
| | | | Cracking | NONE | – | – | Minor | Major |
| | | | Loosening | NONE | – | – | Minor | Major |
| | | | Falling | NONE | – | – | Minor | Major |
| | | | Deformation | NONE | – | Minor | – | Major |
| Hand Rail Curb | Steel | | Corrosion | NONE | Surface Minor | Surface Major | Loss of Section Minor | Loss of Section Major |
| | | | Cracking | NONE | – | – | Minor | Major |
| | | | Loosening | NONE | – | – | Minor | Major |
| | | | Falling | NONE | – | – | Minor | Major |
| | | | Failure | NONE | – | – | – | Present |
| | | | Discoloration | NONE | Minor | Major | Scaling Minor | Scaling Major |
| | | | Deformation | NONE | – | Minor | – | Major |

**Table 10.10 Judgement Ranking of Recurrent Inspection (3)**

| Member | | | Damage | Damage Ranking A | B | C | D | E |
|---|---|---|---|---|---|---|---|---|
| Hand Rail Curb | Concrete | | Cracking | NONE | – | Interval more than 50cm | Interval less than 50cm | Width Several Millimeter |
| | | | Scaling Corrosion of Rebar | NONE | – | Exposed Rebar Minor | Exposed Rebar Major | Loss of Section |
| | | | Free Lime | NONE | Present | – | – | – |
| | | | Honeycombs | NONE | Minor | Major | – | – |
| | | | Discoloration | NONE | Minor | – | Major | – |
| | | | Loss of Member | NONE | – | Minor | – | Major |
| Asphalt Pavement | | | Step Corrugation | NONE | Less than 20mm | 20mm ~ 40mm | More than 40mm | – |
| | | | Pot Holes | NONE | Less than 10mm | 10mm ~ 30mm | More than 30mm | – |
| | | | Cracking | NONE | Less than 5mm | 5mm ~ 10mm | More than 10mm | – |
| | | | Rutting | NONE | Less than 20mm | 20mm ~ 40mm | More than 40mm | – |
| | | | Leakage | NONE | Present | Present | – | – |
| Expan-sion | Joint | Rubber | Abnormal Condition of Space | NONE | – | – | Present | – |
| | | | Failure | NONE | – | – | – | Present |
| | | | Abnormal Sound | NONE | – | – | Present | – |
| | | | Deformation | NONE | – | Minor | – | Major |
| | | | Loss of Member | NONE | – | Minor | – | Major |
| Drainage | | | Corrosion | NONE | Surface Minor | Surface Major | Loss of Section Minor | Loss of Section Major |
| | | | Cracking | NONE | – | – | Minor | Major |
| | | | Loosening | NONE | – | – | Minor | Major |
| | | | Falling | NONE | – | – | Minor | Major |
| | | | Failure | NONE | – | – | – | Present |
| | | | Interior of Paint | NONE | – | Present | – | – |
| | | | Discoloration | NONE | Minor | Major | Scaling Minor | Scaling Major |
| | | | Leakage | NONE | – | – | Present | – |
| | | | Deformation | NONE | – | – | Present | – |
| | | | Stuffed | NONE | – | – | Present | – |
| | | | Loss of Member | NONE | – | Minor | – | Major |

**Table 10.10 Judgement Ranking of Recurrent Inspection (4)**

| Member | Damage | Damage Ranking | | | | |
|---|---|---|---|---|---|---|
| | | A | B | C | D | E |
| Drainage | Corrosion | NONE | Surface<br>Minor | Surface<br>Major | Loss of Section Minor | Loss of Section Minor |
| | Cracking | NONE | – | – | Minor | Major |
| | Loosening | NONE | – | – | Minor | Major |
| | Falling | NONE | – | – | Minor | Major |
| | Failure | NONE | – | – | – | Present |
| | Paint of Interior | NONE | – | Major | Scaling Minor | Scaling Major |
| | Deformation | NONE | Minor | Mnor | – | Major |
| | Discoloration | NONE | Minor | – | Major | – |
| | Loss of Member | NONE | – | Minor | – | Major |

12) Evaluation Standards of Overall Soundness

The soundness evaluation of bridges is based on the evaluation standards taken from the survey results of each bridge and calculates ultimate load-bearing ability by the soundness evaluation formula which evaluates by judging durability, active load and heavy-load traffic as well as service life.

The coefficient of weight which is substituted in the soundness evaluation formula is shown in Table 10.11 as grades according to evaluating factors.

* Soundness evaluation points for concrete bridges

Overall soundness evaluation (at x bt) = Evaluation points for each item (at) x Weight factor (bt)

**Table 10.11 Evaluation of Coefficient of Weight and Evaluation Factor**

| | | Evaluation Item | Evaluation Points (at) | | Weight Factor (bt) | Points at x bt |
|---|---|---|---|---|---|---|
| Durability | Super-structure | Main Girder | A-1, B-2, C-3, D-4, E-5 | | 0.400 | |
| | | Cross Girder | A-1, B-2, C-3, D-4, E-5 | | 0.100 | |
| | | Bridge Deck | A-1, B-2, C-3, D-4, E-5 | | 0.250 | |
| | | Supports | A-1, B-2, C-3, D-4, E-5 | | 0.050 | |
| | Sub-structure | Abutment | A-1, B-2, C-3, D-4, E-5 | | 0.100 | |
| | | Column (Pier) | A-1, B-2, C-3, D-4, E-5 | | 0.100 | |
| Load Character-istics | Live Load and Heavy Vehicle | Weight per axle less than 7.0 ton, little heavy traffic | | 1 | 0.350 | |
| | | Weight per axle more than 7.0 ton, with heavy traffic | | 3 | 0.350 | |
| | Year Bridge Completed | Completed after 1975 (in service less than 20 years) | | 1 | 0.150 | |
| | | Completed before 1975 (in service more than 20 years) | | 3 | 0.150 | |
| Total Points | | | | | | |

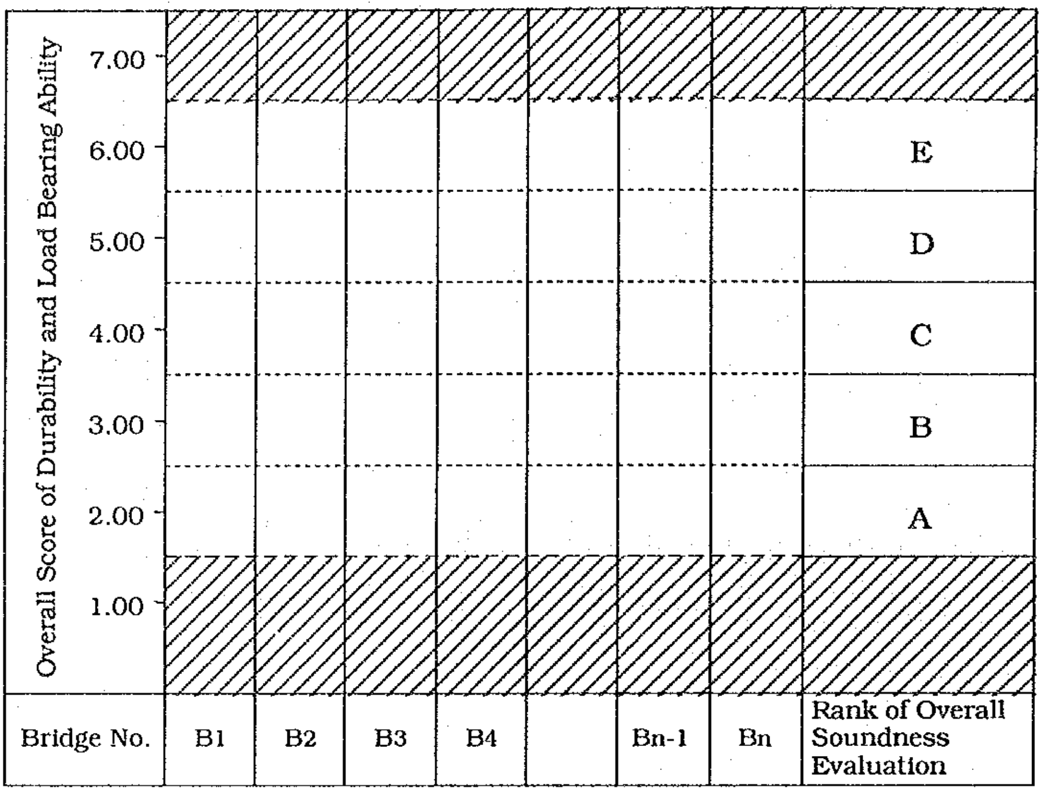



**Fig. 10.5 Overall Soundness Evaluation Graph**

(13) Emergency Check-up

An emergency check-up is conducted before and/or after an earthquake, heavy rain or monsoon in affected area, or in case of reported damage, or in case of discovery of damage during routine check-up.

1) Method of Inspection

| | |
|---|---|
| In case of heavy rains : | Look for water puddles on road surface, fallen rocks, trees or boulders carried by water current, inspect water level below bridge. |
| In case of monsoons : | Inspect bridge for abnormal vibration or sound. |

2) Flow of Inspection

The flow of inspection for an emergency check-up is shown in Fig. 10.6.

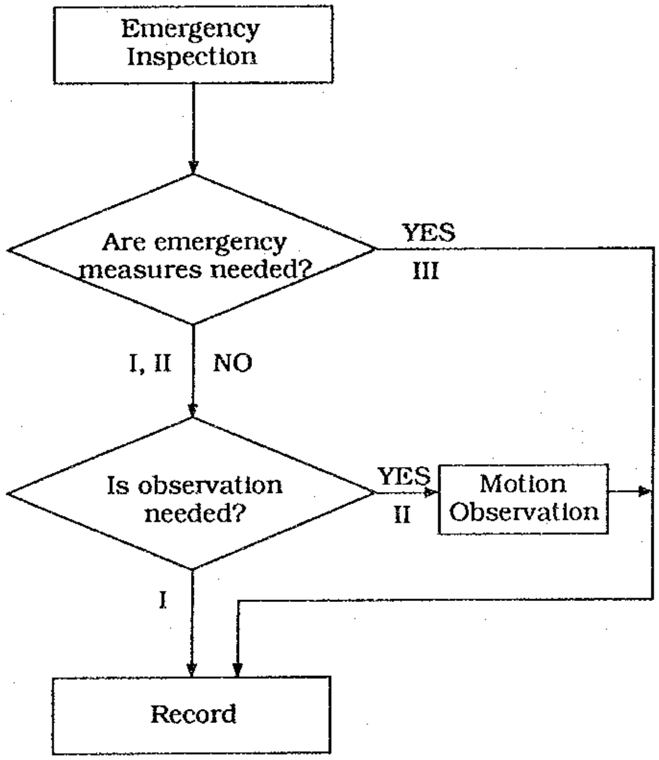



**Fig. 10.6 Flow of Emergency Inspection**

3) Standards of Evaluation

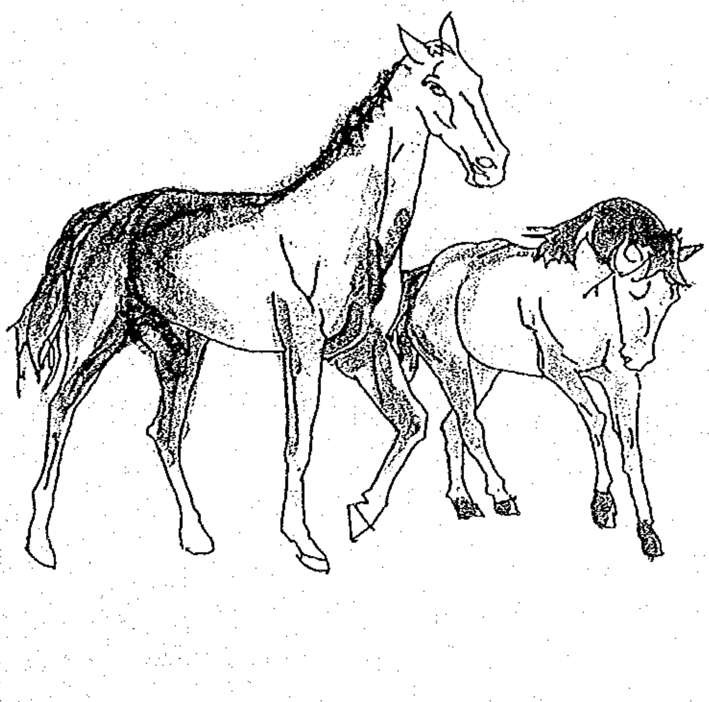
The results of the check-up are evaluated according to the evaluation standards as shown in Table 10.12.

"Emergency Measures" as referred to in rank III: traffic control, traffic stoppage, detouring, vehicle load regulations, immediate repair or reinforcement.

**Table 10.12 Evaluation Standard of Emergency Inspection**

| Rating | | Condition | Action Taken |
|---|---|---|---|
| I | Sound | No damage noticed | — |
| II | Fairly Unsound | Damage Found | Motion Observation |
| III | Dangerous | Large Damage Found | Make Emergency Repair |

# CHAPTER 11 CONCLUSION AND RECOMMENDATION



# CHAPTER 11

# CONCLUSIONS AND RECOMMENDATIONS

## 11.1 Conclusions

The bridges in the sultanate of Oman are almost all made of concrete due to the material obtainment situation, and concrete bridges will continue to predominate in the future.

While the existing bridges have been designed based on various country codes, however, almost all of those that applied AASHTO HS20-44 standard. It was found that the material properties of the concrete and reinforcing bars vary by bridge, and also there exist almost no documents from the design stage or construction records from the construction stage.

Therefore, the current conditions of the bridges were mainly examined from field investigations. They are summarized as follows.

(1) Reinforced-concrete bridges

- Almost all the superstructures had cracking in parts. An examination of cracks in main girders revealed that no new crack initiation or propagation had occurred after first repair. Judging from this, the cracks formed upon a temporary heavy loading.
- Concrete neutralization is not advanced and the compressive strength of the concrete is still sufficient. Deterioration is not great.
- Despite the cracks in the concrete, little rusting of the reinforcing bars has occurred.
- The pavement near the bridge expansion joints is not smooth, thereby impairing road maneuverability.
- Some bridges have cracks in part of their substructure, but no substructure settlement or inclination has occurred.

- There are scoured areas around some substructures.

(2) Pre-stressed concrete bridges

- There are bridges with structural defects, such as a lack of cross beams.
- The concrete slabs were made by pouring concrete while using precast plates as forms. However, the precast slabs and the poured concrete have not merged into a single entity. In addition, because the slab concrete is thin, the slabs have little strength. Cracking occurred as a consequence.
- There are no problems with the substructures.

(3) Loading test results

Upon a comparison between theoretical values and measured values of main girder reinforcing bar stress and main girder deflection as measured in loading tests, it was found that the measured values were less than the theoretical values and the actual rigidity of the bridge is higher than that assumed in the design. Consequently, the load bearing capacity is also higher than the design value.

Converting the load bearing capacity of the test results into an equivalent axle load, bridge functionality could be assured with a maximum axle load of 14.5t for Bridge Nos. 1 and 6 and 10.8t for all other bridges.

## 11.2 Recommendations

From the investigation results, the following recommendations are proposed to assure the functionality of existing bridges and for the construction of bridges in the future.

<u>For Existing Bridges</u>

- Restrictions of axle load of vehicles
- To smooth out the bridge surface by paving to lessen vehicular impact load
- To repair cracks on RC bridge by mortar injection method and to check up progress of cracks

- To repair or reinforce the structural defects of PC bridges (for example, replacement of slabs, installation of cross beam, etc.)

- To establish a maintenance and rehabilitation system that includes a bridge inspection system, and to file the records of degree of soundness for all bridges which include as-built drawings, construction records and inspection records, and to carry out routine monitoring.

For New Bridges

- Store and file such documents as the design standards, design report, at design stage.

- Store and file as-built drawings, records of material types, quality control results, etc.