Table 2.4: Maximum Bending Moments for Two Lane Simply Supported Spans of Bridge Decks Due to Loads of Various Countries

Maximum Bending Moment Inclusive of Impact (kN.m)

Span (m)	*U.K. Type HA Loads*	*U.K. Type HB Loads*	*India IRC Loads*	*Germany Class-60 Loads*	*Japan L-20 Loads*	*Sweden*	*France*	*North America AASHTO HS:20-44 Loads*	*New Zealand*
5	488	838	687	1224	827	640	780	462	462
25	6312	8914	5680	9904	6125	5819	6580	4044	4970
50	17132	21914	12496	21660	17016	15838	17740	9194	11476
75	30234	35290	23486	39754	32523	26250	31696	18310	18310
100	45750	49112	42880	62536	50241	37300	48212	30368	30368

Table 2.5: Maximum Shear Forces for Two Lane Simply Supported Spans of Bridge Decks Due to Loads of Various Countries

Maximum Shear Force Inclusive of Impact (kN)

Span	*U.K. (m)*	*U.K. Type HA Loads*	*India Type HB Loads*	*Germany IRC Loads*	*Japan Class-60 Loads*	*Sweden L-20 Loads*	*France*	*North America AASHTO HS:20-44 Loads*	*New Zealand*
5	398	804	594	1142	661	512	718	424	424
25	1010	1619	978	1614	980	931	1138	738	894
50	1386	1856	1174	1744	1361	1267	1420	820	1002
75	1612	1952	1572	2128	1735	1400	1690	1058	1212
100	1830	2018	1996	2508	2010	1492	1928	1294	1516

The railway tracks are classified according to the importance of traffic as main and branch lines. The three types of gauges used in the Indian Railways are:

1. Broad gauge (BG): 1676 mm (5'-6")
2. Metre Gauge (MG): 1000 (3'-3.375")
3. Narrow gauge (NG): 762 mm (2'- 6")

At present, the Indian Railways have adopted the unigauge policy with the broad gauge as the standard gauge throughout the country. Consequently many important old lines are being converted into broad gauge.

The various loads and forces to be considered in the design of bridge members are:

1. Dead and live loads
2. Dynamic effects
3. Cetrifugal force due to curvature of track
4. Temperature and frictional effects
5. Racking force
6. Wind and earthquake forces

A comparative analysis of the Indian, British and American methods of high strength concrete mix design has been presented by Krishna Raju and Krishna Reddy[10] based on experimental investigations. M-45 grade concrete was designed and tested according to the standard procedure resulting in the following observations:

1. The British and American methods resulted in higher water/cement ratio compared to the Indian Standard Method. The water/cement ratio varied from 0.30 for I.S. to 0.44 for the British method.
2. The aggregate/cement ratio used in the Indian, American and British methods were 2.7, 3.4 and 5.3 respectively.
3. The Indian method resulted in the highest cement content of 591 kg/m^3 of concrete while the British method used the least cement content of 356 kg/m^3.
4. The A.C.I. method of mix design resulted in concrete of compressive strength very nearly equal to the specified characteristic compressive strength with the most economical cement content in comparison with other methods.

In these investigations, the cement used was of the grade C-53, but now the market is flooded with better quality and high grade cements like Birla Super, L&T, A.C.C., Coramendel, Ultra Tech, Gujarat Ambuja and various other brands of cement. Most of these cements more than satisfy the various Indian Standard Code specifications[11, 12] and hence the design of concrete mixes of characteristic strength in the range of M-40 to M-60 does not pose any serious problems. Using good quality aggregates and modern cements, even the nominal mix proportions of 1 : 1.5 : 3 or 1 : 1 : 2 with controlled water/cement ratios in the range of 0.35 to 0.4 and with proper compaction using vibrators can result in concrete having characteristic compressive strength exceeding M-40.

The use of light weight aggregate for prestressed concrete construction is well established since 1955 with the main advantage of reduction in the self weight of the structure. The light weight criterion becomes important especially in long span structures where dead load forms the major portion of the total design load on the structure or when the self weight of the member is a factor to be considered in transportation and erection as in the case of precast concrete construction. Teychenne[13] has developed empirical graphs that relates the important parameters of light weight concrete. ACI Standard[14] provides a generally applicable method for selecting mix proportions of light weight concrete using different types of light weight aggregates. An excellent survey of the effective utilization of light weight concrete in prestressed concrete structures is reported by Gerwick[15].

The modulus of elasticity of concrete generally used for computations of short term and long term deflections of post tensioned prestressed concrete beams as recommended in IRC: 18-2000 is expressed as,

$$E_c = 5000\sqrt{f_{ck}}\ \text{N/mm}^2$$

where f_{ck} = characteristic compressive strength of concrete expressed in N/mm^2. The code also recommends varying creep strain in concrete depending upon the maturity of concrete at the time of stressing as a percentage of the characteristic compressive strength of concrete. The loss of stress in steel due to shrinkage of concrete is to be estimated from the values of strain due to residual shrinkage which varies from 4.3×10^{-4} for concrete at the age of 3 days to a value of 1.5×10^{-4} for concrete at the age of 90 days.

tensile strength decreases with increase in the diameter of the wires. In contrast to mild steel, high tensile steel wires do not exhibit any well defined yield point and it is necessary to refer to the 0.2 per cent proof stress corresponding to the specified permanent strain. It is prescribed that the 0.2 per cent proof stress for high tensile steel wires and bars should be not less than 85 and 80 per cent respectively of the minimum specified tensile strength. Extensibility of the tendons near the ultimate stress is also an important requirement to facilitate progressive failure of the prestressed concrete structural element. To prevent the possibility of brittle fracture, the Indian Standard Code prescribes a minimum percentage elongation varying from 2.5% for wires to 10% for bars. Prestressed concrete bridge decks requiring large prestressing forces are prestressed using strands. The mechanical properties of uncoated stress relieved strand specified in IS: 6006-1983 is compiled in Table 3.4.

Relaxation of stress in steel is required for the computation of losses in prestress. The IRC: 18-2000 code recommends the relaxation loss as a percentage of the initial stress which varies from 0.5 to 0.8 times the characteristic tensile strength of the steel. The relaxation loss varies from zero to 9% corresponding to the initial stress varying from $0.5f_p$ to $0.8f_p$.

The loss of stress due to friction between the tendons and the duct or sheath depends upon the steel stress at jacking end, the length and curvature of the cable. Different values are recommended in the code for the values of the coefficient of friction and the wobble coefficient per unit length depending upon the type of duct or sheath and the high tensile steel which may be in the form of wires or strands. For design purposes, the nominal value of modulus of elasticity of steel recommended is compiled in Table 3.6.

Table 3.6: Modulus of Elasticity of Steel (E_s) (IRC: 18-2000)

Sl.No.	*Type of Steel*	*Modulus of Elasticity (N/mm²)*
1	Plain hard drawn wires (conforming to IS: 1785 & IS: 6003)	2.1×10^5
2	High tensile steel bars rolled or heat treated (conforming to IS: 2090)	2.0×10^5
3	High tensile strands (conforming to IS: 6006)	1.95×10^5

3.4. UNTENSIONED STEEL OR SUPPLEMENTARY REINFORCEMENT

Reinforcement used as untensioned steel in the form of longitudinal bars and stirrups comprise the following:

1. Mild steel and medium tensile steel bars conforming to IS: 432 (Part-I)[22]
2. High strength deformed steel bars conforming to IS: 1786[23]
3. Hard drawn steel wire fabric conforming to IS: 1566[24]

Supplementary reinforcements are required in prestressed concrete beams and slabs to safeguard against shrinkage cracks and for resisting shear forces. Normally stirrups and hanger bars are made up of untensioned reinforcement. They are also provided as anchorage zone reinforcement at the end blocks of post tensioned prestressed concrete beams.

1. Workability test
2. Transverse load rating test
3. Tension load test
4. Water loss test
5. Bond test
6. Compression test.

The details of these various tests are outlined in Appendix I A and I B of IRC: 18-2000.

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