HANDBOOK
ON
ROADS AND BRIDGES

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ROADS AND BRIDGES

1.1 ROADS

1. Preamble

The Government Roads comprise of National Highways (NH), State Highways (SH), Major District Road (MDR), Other District Roads (ODR), and Cross Drainage Works like bridges, Causeways, Culverts, Road Over Bridge (ROB) and Road Under Bridge (RUB).

NH: Main highways running through the length and breadth of the Country connecting major ports, State Capitals, large industrial and tourist center.

SH: Arterial routes of a State linking District Headquarters and important cities within the State and connecting them with NH or Highways of the neighbouring States.

MDR: Important roads within a district serving areas of production and markets and connecting those with each other or with main highways

ODR: Roads serving rural areas of production and providing them with outlet to market centers, taluk headquarters, Block Development headquarters or other main roads.

The roads are again grouped as Single lane (3.5 m), intermediate lane (5.5 m), Double lane (7m with kerb or 7.5 m without kerb) and multiple lanes (addl. 3.5 m for each lane) depending upon the width of Carriageway. On village roads, the width may be restricted to 3 m. Roads are broadly classified as Rural Roads and Urban Roads.

To design and construction of the roads, Standards prescribed in Indian Road Congress (IRC) Specifications and Ministry of Road Transport and Highways (MORT&H) Specification are to be observed. Some of the IRC Specifications frequently used for road construction are

IRC 37:2001 –Guidelines for the design of Flexible Pavement

IRC: SP-20:2002: Rural Roads Manual

IRC 81:1997 & 81:2001- Guidelines for Strengthening Road pavements using Benkelman Bean Deflection Technique.

IRC 58:1974 - Guidelines for the Design of Rigid Pavements for Highways

IRC 15:1981- Standard Specification and code of Practices for construction of concrete roads

IRC 86:1983 – Geometric Design Standards for Urban Roads in Plains]

IRC 73:1980 – Geometric Design Standards for Rural (Non-urban)-Highways

IRC 64:1990 - Guidelines for capacity of Roads in Rural Areas

IRC 37:2001 specification is used for designing flexible pavements which includes bituminous surfacing, granular base and granular base with sub base courses conforming to IRC Standards or to Section 500 and 400 of the Specification for Roads and Bridge Works, Ministry of Road Transport and Highways. For construction of new pavement IRC 37:2001 and strengthening the existing pavement, IRC 81:1997 will apply. IRC : SP-20:2002 is to be adopted for formation of road, construction of culvert and minor bridge in village Roads and ODR having projected traffic intensity less than 450 commercial vehicle per day (CVPD).The input and parameter for appropriate design of the pavement is based on traffic and soil strength.

2. Traffic

The traffic in terms of the cumulative number of Standard axles (8160 Kg) to be carried by the pavement during the design life. The following information is needed:

i) initial traffic after construction in terms of number of commercial vehicles per day (CVPD)
ii) Traffic growth rate during the design life in percentage
iii) Design life in number of years
iv) Vehicle damage factor (VDF)
v) Distribution of Commercial traffic over the carriageway.

a) Initial Traffic: Estimate of initial daily average traffic flow for any road should normally be based on atleast 7 days, 24 hour classified traffic counts. In case of new roads, traffic estimates can be made on the basis of potential land use and traffic on existing routes in the area.

b) Traffic growth rate: Traffic growth rates should be estimated by study. If adequate data is not available, average annual growth rate of 7.5% may be adopted. The factor is reduced to 6% for roads desiged adopting IRC:SP 20-2002

c) Design life: The Design life is defined in terms of cumulative number of Standard axles that can be carried before strengthening of the pavement. Normally the pavement for NH & SH is the designed for life of 15 years, Expressways and Urban roads for 20 years and other roads for 10 to 15 years.

When it is not possible to provide the full thickness of pavement at the time of initial construction, stage construction technique should be resorted to. Roads in Rural areas should be designed for a design life of 10 years.

d) Vehicle damage factor (VDF): VDF is arrived at from axle load surveys. The indicative value of VDF factor is given below:

e)

Initial traffic in terms of commercial vehicle per day	**Terrain**	
	Rolling/Plain	**Hilly**
0-150	1.5	0.5
150-1500	3.5	1.5
More than 1500	4.5	2.5

e. Distribution of Commercial traffic over the carriage way:

i) Single lane : Design should be based on total number of commercial vehicle in both directions multiplied by two

ii) Two lane (single Carriageway) : 75% of the total number of commercial vehicle in both the direction.

iii) Four lane (single Carriage way) : 40% of the -do-

iv) Dual Carriageway: 75% of the number of commercial vehicle in each direction. For dual 3 lane and dual 4 lane carriageway, the distribution factor will be 60% and 45% respectively.

Computation of design traffic under IRC 37: 2002

The design traffic is considered in terms of Cumulative number of standard axles to be carried during the design life of the road. Computed by the equation

$$N = \frac{365x\,[(1+r)^n - 1]}{r} \times A \times D \times F$$

Where

N: The cumulative number of standard axles to be catered for in the design in terms of MSA
A: Initial traffic in the year of completion of construction in terms of numbr of commercial vehicles per day
D: Lane distribution factor
F: VDF
n: Design life in years
r : Annual growth rate of commercial vehicles (for 7.5% annual growth rate r=0.075)

The traffic in the year of completion is estimated using the following formula:

$$A = P\,(1+r)^x$$

Where P = Number of Commercial vehicle as per last count
x = Number of years between the last count and the year of completion of construction

Computation of design traffic under SP 20:2002

The traffic for design life is computed as –
Number of commercial vehicles per day for design $A = P(1+r)^{n+x}$
Where r= Annual growth rate of commercial vehicle (i.e 6%)
P, x & n = as above

3. Soil Parameter:

One of the main parameter designing pavement is the quality of soil in the roadway. For design purpose, top 500 mm portion of the roadway/embankment if formed with filling materials, immediately supporting the pavement, termed as sub grade, is considered for design purposes. Whereas in rural road the top 30 cum of cutting or embankment at the formation level is considered as sub grade.

Sub grade:

Sub grade is normally formed with natural earth

- Compacted to 97% of dry density IS 2720 (Part 8).
- Materials used for sub grade construction should have the dry density of not less than 1.75 gm/cc
- Wherever necessary, the original ground shall be leveled to facilitate placement of first layer of embankment, scarified, mixed with water and then compacted by rolling so as to achieve minimum dry density. In case where the difference between the subgrade level and the ground level is less than 0.5m (0.3 m for Rural Roads) below the subgrade level watered and compacted in layers to achieve not less than 97% dry density (clause 305.3.3 of MORTH)
- When the soil does not fulfill the requirements of normal subgrade soil, a stabilization technique can be used to modify and improve the same. Stabilisation is of different type viz., stabilization with lime, sand, cement, coal ash, soft aggregates, gravel/moorum and mechanical stabilization etc., as stipulated in IRC SP 20: 2002 and other IRC's & MORTH specifications.
- As far as possible a non expansive soil should not be used for the sub grade
- The sub grade strength is assessed in terms of the CBR (California Bearing Ratio)
- The design should be based on the CBR value of the weakest soil type proposed to be used for subgrade construction or encountered extensively at subgrade level over a given section of the road.
- Pavement thickness on new road may be modified at intervals (say 1 Km) based on the CBR values.
- Where the variation in CBR test is + or – 1 and + or – 2 for soil sample having CBR value less than 5% and 5-10% respectively then the CBR value should be the average of test from atleast 6 samples.

- Where CBR value of sub grade is less than 2% a capping layer of 150 mm thickness of materials with a minimum CBR of 10% shall be provided in addition to the sub base. (normally sand would be used)
- Where embankment was formed, the CBR value of sub grade has to be tested and pavement design modified, if necessary.

Preparation of sub grade & sub base (IRC 15 :1981)

- Sub grade be uniformly compacted which extends at least 300 mm on either side.
- Sub grade be properly drained
- Sub base may of (a) granular materials (one layer flat brick soling, with sand under one layer of WBM or two layers of WBM, or well graded granular materials like gravel, brick metal, laterite, etc.)

  Or (b) stabilized soil (soil or moorum stabilized with lime or lime fly ash or cement having CBR of 50% after 7 days curing

  Or (c) Semi rigid materials (lime burnt clay or lime fly ash concrete or lean cement concrete fly ash conforming to IRC 74 : 1979.
- Thickness of sub base should be 15 cm when material (a) & (b) used. This may, however reduced to 10 cm for semi rigid materials.
- Where sub grade consists of heavy clay such as black cotton soil, the sub base should be laid over 15 cm thick blanket course consisting of non plastic granular materials like local sand, gravel, etc or local soil stabilized with lime.
- The sub base or blanket course may be laid over properly compacted sub grade to give uniform support

4. Pavement thickness & composition other than rural roads**:**

- The Pavement construction is of two type Flexible pavement and rigid pavement The Pavement thickness chart is given in IRC 37:2001 for traffic in the range of 1 to 150 msa and for CBR value of sub grade ranging from 2% to 10%. The pavement thickness to be provided consists of granular sub base, granular base and bituminous surfacing. For traffic exceeding 150 msa, pavement design for 150 msa may be adopted and further strengthening carried later for extended life adopting IRC 81:1997 – To

design the pavement, IRC specification are to be followed and for construction standards and guidelines, specifications stipulated in MORTH specification has to be followed.

For the design of pavements to carry traffic in the range of 1 to 10msa, the pavement thickness chart is given in Fig 1 and for traffic in the range of 10-150 msa. The pavement thickness chart is given in Fig 2. The design curves relate pavement thickness to the cumulative number of standard axles to be carried over the design size for CBR values of subgrade ranging from 2 percent to 10 percent. The thickness deducted from Fig 1 or Fig 2 for the given CBR value and design traffic is the total pavement thickness to be provided and consist of granular sub base, granular base and bituminous surfacing. The recommended designs giving minimum thickness and compositions of pavement layers for new constructions are given below in Table 1 and 2.

Table 1 (Traffic intensity 1-10 msa)

CBR Value of sub grade	**Pavement composition**	**Thickness of pavement compositions for various traffic intensity in mm**				
		1 msa	**2 msa**	**3 msa**	**5 msa**	**10 msa**
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
2%	GSB	435	440	440	450	460
	GB	225	225	250	250	250
	BM		50	60	70	100
	PC		20	20	-	-
	SDBC	20	-		25	40
	TOTAL	660	715	750	795	850
3%	GSB	435	335	335	335	380
	GB	225	225	250	250	250
	BM	-	50	60	60	-
	DBM	-	-	-	-	90
	PC	20	20	-	-	-
	SDBC	-	-	25	25	-
	BC	-	-	-	-	40
	TOTAL	550	610	645	690	760
4%	GSB	255	265	280	285	330
	GB	225	225	250	250	250
	BM	-	50	50	-	-
	DBM	-	-	-	60	80
	PC	20	20	20	-	-
	SDBC	-	-	-	25	-
	BC	-	-	-	-	40

	TOTAL	480	540	580	620	700
	GSB	205	215	230	250	300
5%	GB	225	225	250	250	250
	BM	-	50	50	-	-
	DBM	-	-	-	55	70
	PC	20	20	20	-	-
	SDBC	-	-	-	25	-
	BC	-	-	-	-	40
	TOTAL	430	490	580	580	660
6%	GSB	165	175	190	210	260
	GB	225	225	250	250	250
	BM	-	50	50	-	-
	DBM	-	-	-	50	65
	PC	20	20	20	-	-
	SDBC	-	-	-	25	40
	BC	-	-	-	-	-
	TOTAL	390	450	490	535	615
7%	GSB	150	150	160	180	230
	GB	225	225	250	250	250
	BM	-	50	50	50	-
	DBM	-	-	-	-	60
	PC	20	20	20	-	-
	SDBC	-	-	-	25	-
	BC	-	-	-	-	40
	TOTAL	375	425	460	505	580
8%	GSB	150	150	150	150	200
	GB	225	225	250	250	250
	BM	-	50	50	-	-
	DBM	-	-	-	50	60
	PC	20	20	20	-	-
	SDBC	-	-	-	25	-
	BC	-	-	-	-	40
	TOTAL	375	425	450	475	550
9% & 10%	GSB	150	150	150	150	200
	GB	225	225	250	250	250
	BM	-	50	50	-	-
	DBM	-	-	-	50	50
	PC	20	20	20	-	-
	SDBC	-	-	-	25	-
	BC	-	-	-	-	40

	TOTAL	375	425	450	475	540

Table 2 (Traffic intensity 10-150 msa)

CBR value of sub grade	Pavement composition	Pavement compositions for various traffic intensity in mm					
		10 msa	20 msa	30 msa	50 msa	100 msa	150 msa
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
2%	GSB	460	460	460	460	460	460
	GB	250	250	250	250	250	250
	DBM	100	130	150	175	195	215
	BC	40	40	40	40	50	50
	TOTAL	850	880	900	925	955	975
3%	GSB	380	380	380	380	380	380
	GB	250	250	250	250	250	250
	DBM	90	120	140	160	180	210
	BC	40	40	40	40	50	50
	TOTAL	760	790	810	830	860	890
4%	GSB	330	330	330	330	330	330
	GB	250	250	250	250	250	250
	DBM	80	110	130	160	170	190
	BC	40	40	40	40	50	50
	TOTAL	700	730	750	780	800	820
5%	GSB	300	300	300	300	300	300
	GB	250	250	250	250	250	250
	DBM	70	100	120	140	150	170
	BC	40	40	40	40	50	50
	TOTAL	660	690	710	730	750	770
6%	GSB	260	260	260	260	260	260
	GB	250	250	250	250	250	250
	DBM	65	90	105	125	140	160
	BC	40	40	40	40	50	50
	TOTAL	615	640	655	675	700	720
7%	GSB	230	230	230	230	230	230
	GB	250	250	250	250	250	250
	DBM	60	90	110	130	145	165
	BC	40	40	40	40	50	50
	TOTAL	580	610	630	650	675	695

8%	GSB	200	200	200	200	200	200
	GB	250	250	250	250	250	250
	DBM	60	85	100	120	140	160
	BC	40	40	40	40	50	50
	TOTAL	550	575	590	610	640	660
9%	GSB	200	200	200	200	200	200
	GB	250	250	250	250	250	250
	DBM	50	80	95	115	135	155
	BC	40	40	40	40	50	50
	TOTAL	540	570	585	605	635	655
10%	GSB	200	200	200	200	200	200
	GB	250	250	250	250	250	250
	DBM	50	75	90	110	130	150
	BC	40	40	40	40	50	50
	TOTAL	540	565	580	600	630	650

Where GSB = Granular Sub Base, GB = Granular base, BM = Bituminous Macadam, DBM = Dense Bituminous Macadam, PC = Premix Carpet with seal coat, SDBC = Semi Dense Bituminous concrete, BC = Bituminous concrete

Note: For intermediate traffic ranges, the pavement layer thickness will be interpolated linearly (clause 4.3.3 of IRC 37:2001)

a. Sub base:

--Material comprise natural sand, moorum, gravel, metal, laterite crushed stone etc. and

--Should have liquid limit and plasticity index of not more than 25 and 6 respectively

--Should have CBR value minimum of 20% for cumulative traffic upto 2 msa and 30% exceeding 2 msa.

-- Where stage construction is adopted for pavements, the thickness of subbase shall be provided for ultimate pavement section for the full design life.

--for drainage consideration the granular sub base should be extended over entire formation width in case of the sub grade soil is of relatively low permeability. The thickness of sub base in the extended portion should not be less than 150 mm for traffic less than 10 msa and 200 mm for design traffic of 10 msa & above. To achieve the stipulated CBR value jobmix formula (using gravel, gravel with sand, quarry dust etc) adopting MORTH specification IV th revision is to be adopted.

b. Base course:

Granular base comprises water bound macadam (WBM), wet mix macadam (WMM) or other equivalent granular construction

-minimum 225 mm thickness for traffic upto 2 msa and 250 mm for traffic exceeding 2 msa
-where road carrying traffic morethan 10 msa, the thickness of WBM base shall be increased from 250 mm to 300 mm (i.e. 4 layers of WBM grade II and III each of 75 mm compacted thickess) with corresponding reduction in the sub base thickness keeping the over pavement thickness unchanged

-for heavy traffic road use WMM

-WBM in layers of 75 mm thick of grade II & III used

-Built up spray grout (BUSG) shall also be used for base in a single course in pavement

c. Bituminous Surfacing:

-Comprise of either a wearing course or a binder course with wearing course depending on traffic intensity and structural requirements

-Wearing course—open grade premix carpet, surface dressing, semi dense bituminous carpet (SDBC), Bituminous Concrete (BC)

-Binder course – Bituminous Macadam (BM), Dense Bituminous Macadam (DBM)

-DBM is recommended for road designed to carry more than 5 msa

-DBM binder course may be preceded by a 75 mm thick BM layer. when this is done, the thickness of DBM layer will be suitably reduced. 10mm BM can be taken as equivalent to 7 mm DBM

-DBM shall be constructed in two layers when it is more than 100 mm

-Mastic asphalt maybe used at bus-stops and intersections.

-Where Wearing course of open graded premix carpet of thickness upto 25mm, should not be counted towards the total thickness of the pavement.

d. Semi rigid pavement:

According to clause 4.2.5 of IRC : 37-1984, when semi-rigid materials such as lean cement concrete/lean cement fly ash concrete were used in flexible constructions and in the absence of an established procedure for the design of composite structures, the thickness of lean cement concrete base/sub-base may be designed for the present with this method using an equivalency factor of 1.5 (i.e. 1 cm lean cement concrete = 1.5 cm WBM)

Where dry lean concrete sub base provided the minimum concrete content in the lean concrete shall be not less than 150 Kg/Cu.M. of concrete. If this minimum cement content is not sufficient to produce concrete of the specified strength (in Section 601.3.4 of MORT&H) it shall be increased as necessary without additional cost compensation to the contractor. (Section 601.3.3 of MORT&H Specification). The maximum size of coarse aggregate shall be 25 mm.

5. Pavement thickness and composition for Rural Roads (IRC:SP-20-2002):

- Applicable to all roads having traffic in the range upto 450 CVPD (i.e village road, ODR)
- The required formation width for rural road(ODR) and village road is 7.5 m. In case of roads of short length connecting one village and hill roads, the formation width can be reduced to 6m (7.1 of IRC SP 20-2002). The recommended carriageway width of ODR and VR in Rural Road is 3.75 m (clause 2.6.4 of IRC SP 20:2002)
- For rural roads, the carriageway width may be restricted to 3.0 m where the traffic intensity is less than 100 motorized vehicle per day and where the traffic is not likely to increase due to situation like dead end, low habitation and difficult terrain.
- Traffic classification for Rural Roads

Curve	No. of Commercial Vehicle per Day (CVPD)
A	0-15
B	15-45
C	45-150
D	150-450

- Pavement thickness

The thickness of pavement is designed on the basis of projected number of commercial vehicles for the design life using current commercial vehicle per day and its growth rate mentioned earlier.

It is expected that rural road will not have more than 450 CVPD in any case.

The design chart given in Fig 5.1 of SP 20:2002 may be referred to obtain the total pavement crust thickness (granular crust thickness) required over the subgrade for the design life of the pavement. Based on the strength of granular materials that unused, the total design thickness is divided into base and sub base thickness.

Bituminous wearing course generally consists of premix carpet with seal coat or two coat surface dressing laid over WMB base.

Pavement thickness for different range of traffic and CBR value is given in Figure 5.2 of SP 20:2002 is indicated below.

CBR value of sub grade	Pavement composition	Pavement composition for various traffic range in mm			
		A curve	B curve	C curve	D curve
(1)	(2)	(3)	(4)	(5)	(6)
2	Capping layer	To be provided	To be provided	To be provided	To be provided
	Sub base	275	365	370	455
	Base (WBM)	150	150	225	225
3	Sub base	200	265	330	320
	Base	150	150	150	225
4	Sub base	125	200	260	315
	Base	150	150	150	150
5	Sub base	100	165	210	260
	Base	150	150	150	150
6	Sub base	75	125	175	225
	Base	150	150	150	150
7	Sub base	60	115	150	175
	Base	150	150	150	150
10	Sub base	30	70	95	125
	Base	150	150	150	150
15	Sub base	-	30	50	75
	Base	150	150	150	150
20	Sub base	-	-	30	30
	Base	150	150	150	150

Surfacing course: surfacing course has to be provided apart from the above pavement composition

<u>a. Subgrade:</u>

-top of 300 mm below the bottom of the subbase
-to be compacted in two layers each 150 mm thickness.
-minimum compacting 100% PD
-where CBR of subgrade is less than 2, pavement designed for a CBR value of 2. A capping layer of 100 mm thickness with material having CBR value 10 provided in addition to the required pavement thickness (normally sand)
-If CBR of the subgrade is greater than 15, no sub base is required but an inverted choke of 25 mm has to be provided above subgrade as per clause 404.32 MORTH Revision IV.
-Inverted choke : If WBM is to be laid directly over the subgrade a 25 mm course of screening (grading B) or coarse sand shall be spread on the prepared sub base. In case of the sand or silty or clayey subgrade it is advisable to lay 100 m coarse sand to act as drainage layer. This will form part of the designed pavement thickness (clause 5.3.2)
Sub Base: sub base materials should have minimum soaked CBR of 15 percent, liquid limit and plasticity index not more than 25 and 6.

c. Base**:**

-Two layers of WBM has to be provided over the sub base
Bottom layer – grade II – 75 mm thick
Top layer – grade III – 75 mm thick

c. Surface Course:

Bituminous surfacing with premix carpet or mix seal surfacing in case of comparatively higher volume of traffic.

d. Semi-Rigid pavement:

-In places subject to heavy rainfall, or soil is very weak semi rigid pavement comprising of Dry lean concrete base and with bituminous wearing course of premix carpet with beat coat or two coat surface dressing.
A granular sub base 100 to 150 mm thickness to full width of formation should be laid below the cement bound layer to provide a working platform and also to act as a drainage /filter layer. The thickness of dry lean concrete base is designed on the basis of projected commercial vehicles/day and CBR value and derived from the design chart under clause 5.5.2 of IRC SP 20-2002.

6. Shoulders construction:

- Structural support to various layers of the pavement besides providing additional space for overtaking maneouvers , parking disabled vehicles and movement of slow moving vehicle (Scooter, three & two wheelers)

- Earthen and paved shoulders
- 15 m wide paved shoulders may be provided on either side of two lane road and for 4 lane it was the policy of Government of India to construct paved shoulder in conjunction with four laning.

- As far as possible paved shoulder when constructed simultaneously with the central pavement, should have the same thickness as pavement of the main carriageway consists of granular sub base 150 mm preferably extended over full formation width to ensure efficient drainage. Base course of WBM or WMM in 3 layers of 75 mm each with the top primed layer besides bituminous wearing course consists of 2 coats of surface dressing, premix carpet, mix seal or SDBC has to be provided over sub-base.

- The texture of the shoulder wearing surface should be different from the main carriageway to ensure clear contrast between them.

(GOI RW/NH-33054/20/88 – DH dated 10.5.89)

7. Concrete Pavement (Rigid Pavement)

Concrete road pavement is designed based on the following IRCs

IRC 15:1981 Standard specification & Code of Practice for construction of Concrete Road

IRC 58:1974 Guidelines of Rigid pavements for Highways Construction of Concrete Road pavements include preparation of sub grade and Sub base underneath these pavement.

- Maximum size of Coarse aggregate is 25 mm
- Cement Content shall not be less than 350 kg per cu. m of concrete. If the minimum cement content is not sufficient to produce specified strength in the field (602.3.2 of MORT & H), it shall be increased without additional compensation under contract. The cement content shall not exceed 425 kg per cu.m of concrete.

8. Strengthening the existing Pavement

- Comprise of profile corrective course and strengthening course.
- For profile corrective course specification 501 of MORT & H specification is to be adopted.
- To strengthen the existing surface IRC 81 : 1997/IRC 81:2001 has to be followed – using Benkeliman Bean Deflection technique.
- Normally designed by the Highways Research Station using overlay thickness design curve with reference to characteristic Defection derived by Benkelman Beam Defection Test for the design traffic.

- The design traffic is completed for a design size of atleast 10 years for major roads. Less important roads may however be designed for shorter period but not less than 5 years.
- The overlay thickness required is deduced from the overlay thickness design curve and the overlay thickness derived is in terms of BM Construction. If other composition (viz., BM, DBC, BC) are to be laid for strengthening, the equivalent overlay thickness to be provided may be determined using equivalency factor as below:

  1cm BM = 1.5 cm WBM/WMM/BUSG

  1cm BM = 0.7 cm DBM/BC/SDBC
- For structural consideration the recommended minimum bituminous overlay thickness is 50 mm BM with additional surfacing course of 50 mm DBM or 40 mm BC.
- When structural deficiency is not indicated from deflection value thin surfacing may be provided to improve the riding quality as required.(viz., 25 mm thick SDBC/BC)
- The overlay thickness Design curve prescribed in IRC:81-1997 is given for reference. The required overlay in terms of BM could be deduced from the curve for the characteristic deflection on the existing pavement worked out by the HRS and for the designed traffic intensity in msa.

9. Strengthening of existing pavement of Rural Roads

IRC SP 20-2002 road with memo No. 3846/2002/AE 4 dated 5.9.2002 of CC (H) Nabard, Chennai.

-If the thickness of the existing pavement is considerable then CBR value of the subgrade assessed. The pavement thickness has to be obtained from Fig 5.1 of IRC SP 20-2002 for the CBR value and design traffic. The existing pavement thickness is to be deducted from the total pavement thickness derived and the balance provided as overlay interms of WBM after picking the B.T surface.

- If the existing thickness of the pavement is less and the PD of the subgrade satisfies the minimum requirements (i.e 1.65 g/cc) but the percentage of compaction is less than 100%, then the existing pavement thickness ignored.
- If the existing thickness of the pavement is less and the PD of the subgrade is less than the minimum requirement then the entire subgrade soil has to be discarded and replaced with good soil and design made treating it as new formation ignoring the existing thickness.

10. Widening the Road

The design width of Road pavement for a traffic volume is equal to its capacity of the Road.

- The design service volume that should be considered for design/ improvement of Road should be the expected volume at the end of the design life. This can be computed by projecting present volume at an appropriate growth rate.
- The present volume of traffic is computed by traffic census using factors for conversion of different type of vehicle into equivalent passenger car unit (PCU) based on their relative interference value as given below:

Vehicle type	Rural Road	Urban Road	
	Equivalency factor for PCU	Equivalent PCU factors percentage composition of vehicle type in traffic stream	
		5%	10% and above
Fast vehicle			
Motor Scooter (Two wheelers)	0.50	0.5	0.75
Passenger Car, Pickup van	1.00	1.0	1.0
Autorickshaw	1.00	1.2	2.0
Agricultural tractor, light commercial vehicle	1.50	1.4	3.7
Bus or trucks	3.00	2.2	5.0
Truck trailer, agricultural tractor – trailer	4.50	4.0	
Slow moving vehicles			
Cycle	0.50	0.4	0.5
Cycle Rickshaw	2.00	0.5	2.0
Hand cart	3.00	2.0	3.0
Horse Drawn vehicle	4.00	1.5	2.0

Bullock cart	8.00	-	-
* for smaller bullock cart a value of 6 will be adopted	**(IRC 64 : 1990)**	IRC	106:1990

Recommended design service for different type of Road in Rural Area

Lane	Terrain	Curvature Degrees Per Km	Design Service volume in PCU
Single lane	Plain	Low (0-50)	2000
		High (above 50)	1900
	Rolling	Low (0-100)	1800
		High (above 101)	1700
	Hilly	Low (0-200)	1600
		High above 200)	1400
Intermediate lane	Plain	Low (0-50)	6000
		High (above 50)	5800
	Rolling	Low (0-100)	5700
		High (above 101)	5600
	Hilly	Low (0-200)	5200
		High above 200)	4500
Two Lane	Plain	Low (0-50)	15000
		High (above 51)	12500
	Rolling	Low (0-100)	11000
		High (above 101)	10000
	Hilly	Low (0-200)	7000
		High (above 201)	5000

- Capacity of two lane road can be increased by providing paved shoulder of 1.5 m width on either side. By which 15 % increase in capacity can be expected vis a vis the value given above.

- A value of 35000 PCU's can be adopted for four lane divided carriage ways. Provision of hard shoulders on dual carriage ways could increase the capacity by 15%

IRC 64:1990

Design Criteria for urban roads

Unlike rural roads, the hourly variation of traffic on urban roads has atleast two distinct peaks. viz. during the morning and evening hours of the day. Further, traffic fluctuates more on urban roads than on rural roads. The urban peak hour traffic constitutes about 8 to 10% of the total daily traffic depending on various factors including the importance of the road in the net work. These factors coupled with other urban characteristics make it necessary to design the urban roads on the basis of peak hour traffic rather than average daily traffic as in the case of rural roads.

(Para 6.1 IRC 106-1990)

ii) Design period of 15 -20 years should be adopted for the arterials and sub-arterials roads and 10-15 years for collector and local streets.

(Para 6.3 of IRC 106-1990)

iii) Capacity standards are fixed normally in relation to the Level of Service (LOS) adopted for design. The Level of Service depends on factors, such as speed and travel time, freedom to maneuver, traffic interruptions, comfort, convenience and safety. Six Levels of Service are recognized commonly designated from A to F.

(Para 5.1 of IRC 106-1990)

iv) Considering the need for smooth traffic flow, it is recommended that normally LOS-C be adopted for design of urban roads. At this level volume of traffic will be around 0.70 times the maximum capacity and this is taken as the "Design Service Volume" for the purpose of adopting design values.

(Para 8.1 of IRC 106-1990)

v) Capacity or Design Service volume is the maximum hourly volume at which vehicle can reasonably be expected to transfers a point or uniform section of a lane or

road way during a given time period.

(Para 4.7 & 4.8 of IRC 106-1990)

vi) Design service volumes for different categories of urban roads corresponding to the above provisions are given below:-

Recommended design service volume of Road in Urban Area

Sl.No.	Type of carriageway	PCUs per hour		
		Total design service volumes for different categories of urban roads		
		Arterial	Sub-arterial	Collector
1	2 lane (one way)	2400	1900	1400
2	2 lane (two way)	1500	1200	900
3	3 lane (one way)	3600	2900	2200
4	4 lane undivided (two way)	3000	2400	1800
5	4 lane divided (two way)	3600	2900	-
6	6 lane undivided (two way)	4800	3800	-
7	6 lane divided (two way)	5400	4300	-
8	8 lane divided (two way)	7200	--	-

Note:

1. Arterial Road: Road with no frontage access, no standing vehicles, very little cross traffic

2. Sub Arterial Road: Roads with frontage access but no standing vehicles and high capacity intersections

3. Collector Road: Roads with free frontage access, parked vehicles and heavy cross traffics

(IRC 106/1990 and clause 4.2.8 of Pocket Book for Highways Engineers)

4. For rural road including ODR and VR where the projected traffic for the design life 10 year less than 450 CVD, the carriageway required would be 3.75 m vide clause 2.6.4 of

IRC SP 20:2002 and hence the necessity for widening does not arise beyond 3.75 m width.

Audit Approaches:

A few cases of audit approaches on pavement design is given below.

1. According to clause 4.2.1.5 of IRC:37-2001, where the CBR value of the subgrade is less than 2%, the pavement design should be based on the CBR value 2% of the subgrade besides a capping layer of 150 mm thick of material with a minimum CBR of 10% (normally sand) in addition to the sub base. But the following are frequently noticed.

a) Though CBR value of the subgrade more than 2% capping layer of 150 mm thick sand provided which is not required and cost there of was avoidable.

b) In case of widening of existing road by box cutting the subgrade would be formed either with filling river sand or carted earth or both. But pavement thickness designed adopting CBR value 2. Here filling of river sand is not required. Pavement thickness has to be redesigned on the basis of CBR value of subgrade formed with carted earth but this was not often done involving extra pavement thickness.

2. Even in some cases where subgrade was formed with carted earth having CBR value more than 7%, (viz 10%,14% etc.) the pavement was designed for CBR value 7% instead of adopting CBR value 10. IRC 37-2001 specifications contemplated design parameters for CBR value upto 10%. This led to extra pavement thickness(vide pavement design catalogue of IRC 37:2001).(e.g) While widening two roads in Madurai that though the CBR value of the existing sub grade in various reaches ranged from 2 to 4%. The entire sub grade was removed to a depth of 500 mm, and replaced with river sand and the pavement was designed with CBR value of 7 for the sub grade. It was also seen that the berms and embankment were formed with earth having a CBR value 14 or 15 with lesser cost. Failure to form the subgrade with carted earth having a CBR more than 10% instead of river sand had resulted in an avoidable expenditure of 27 lakhs (with a further liability of 12 lakhs).

3. According to clause 5.3 of IRC 81:1997, the recommended design life for strengthening of major road should be 10 years and less important roads may however, be designed for a shorter design period. But design life of 15 years is adopted for many cases. This resulted in increase in computation of design traffic in msa and consequent increase in pavement thickness derived from 'Overlay thickness design curve'. This resulted in extra cost.

4. Verify whether latest traffic census was adopted for computation of design traffic in msa and correct CBR value is adopted for computation of pavement thickness. Cases are noticed on extra pavement thickness due to erroneous computation of design traffic. (e.g) The design traffic for strengthening work of Madurai Thondi road was wrongly computed (as 30 msa) for a design life of 15 years instead of 10 years (15

msa). This resulted in providing excess overlay by way of excess thickness ranging from 10 mm to 23 mm. This excess provision of DBM resulted in an extra expenditure of 0.33 lakhs.

While designing the estimates for widening and strengthening 12 radial roads leading to Madurai city, HRS adopted 1996 census instead of 1999 census in respect of nine roads. As per 1999 census there was marked decrease in respect of five roads due to formation of ring roads in 1998, change in flow of traffic to another road, upgraded as NH from 1999. The decrease in traffic required less overlay thickness as per specifications. The adoption of 1996 census resulted in provision of 15 to 100 mm of BM and DBM excess over requirement as per specifications, resulting in extra expenditure of Rs.2.68 crores.

5. Cases where strengthening the existing road sanctioned and Benkelman Bean Deflection Test was carried but and strengthening work not carried. In the meantime special repair work either on flood restoration work or under other scheme carried out and strengthened the pavement. Subsequently normal strengthening work sanctioned and executed without considering the strengthening work/special repairs carried out earlier. This involved extra cost on the work to the extent of addition to the pavement structure.

6. Cases of designing existing the road for strengthening adopting IRC 37:2001 was noticed even without considering the existing pavement thickness of various layer. Though the result of Benkelman Bean Deflection Technique Test result was not available, atleast the existing pavement had to be taken. If not done, the extra pavement thickness has to be worked out and commented.

7. In case of rural road having designed traffic was less than 450 CVPD, IRC: SP 20:2002 has to be adopted. But in many cases ODR having designed traffic less than 450, IRC 37:2001 adopted. Failure to adopt IRC SP 20:2002 resulted in unnecessary extra pavement thickness involving extra cost.

8. Pavement thickness has to be designed based on CBR value and traffic intensity for new road or widening. The pavement thickness has to be modified at intervals (say 1 km) based on the CBR value (vide clause 3.4.6.1 of IRC 37:2001). But uniform pavement thickness was adopted involving extra cost on extra thickness on various layers of pavement.

9. In case of strengthening the existing pavements uniform pavement thickness adopted irrespective of modifying the pavement thickness on the basis of the result.

- ***Where structural deficiency is not indicated from deflection value, thin surfacing may be provided to improve the riding quality as required. But 40 mm BC was provided in many cases instead of 25 mm thick BC or SDBC depending on the traffic intensity.***

Equivalency factor 1 cm thick BM = 0.7 cm thick SDBC/BC/DBM not adopted. The above case led for extra pavement thickness involving extra cost. (e.g) While improving the State roads in and around Tiruppur Town, the CE failed to consider the SDBC of 25 mm and its equivalency factor with reference to granular layer. This resulted in

provision of excess thickness of various layers involving an extra expenditure of Rs 81.52 lakhs.

10. Paved shoulder, cycle tract were constructed adopting same pavement thickness of the main carriageway instead of standard specification prescribed by Government of India in letter dated 10.5.99 involving unnecessary extra pavement thickness resulting in extra cost. (e.g) In widening and strengthening of radial roads, in Madurai, the Chief Engineer designed the paved shoulders in six roads works adopting the composition provided for the main carriageway resulting in an avoidable expenditure of Rd 3.68 crores.

11. Cases of not considering 25 mm SDBC towards total pavement thickness. (e.g) To improve the riding quality of roads provision was made in the estimate for profile correction with DBM 50 mm thick and 40 mm BC as wearing coat. As 25 mm BC is enough for improving the quality as per MORTH guidelines since the roads needed only a thin surface treatment for improving the quality. The provision of additional 15 mm thick resulted in on extra expenditure of Rs 6.33 crores.

12. In case where strengthening and widening was carried out simultaneously, the bituminous binder and wearing course designed for widening portion is adopted for the strengthening portion of the existing carriageway, instead of designing the existing carriageway separately adopting IRC 81:1997 involving unwanted provision of overlay, extra overlay thickness.

13: Clause 6.4 of IRC 64-1990, stipulates that design service volume of traffic that should be considered for design/improvement of a road should be expected volume of traffic at the end of design life after the specific traffic growth rate. The capacity of the road that could cater the traffic for the designed life is indicated in the above table for single intermediate, double lane etc. But cases where widening was carried out (viz., single lane in to intermediate, intermediate to double lane etc.,) irrespective of the fact that the existing road would cater traffic for designed life. This unnecessary widening resulted in extra cost. In respect of two roads the design service volume expected at the end of design life computed on the basis of 1999 census was 10334 PCU and 13852 PCU respectively at the end of design life. The intermediate layer was sufficient to cater the expected volume (5.5 meter wide). But the roads were upgraded as double lane and widened to 7 m width involving excess width of 1.5 m. This lead to an avoidable extra expenditure of Rs 1.65 crore.

14. Cases where rural roads were widened to intermediate/double lane has to be verified and commented for unnecessary widening as clause 2.6.4 of SP 20:2002 stipulated 3.75m width.

REPAIRS AND MAINTENANCE

IRC 82:1982, “Codes of practice for maintenance of Bituminous Surfaces of Highway” prescribes standard for maintenance. Maintenance operation is classified into 3 groups

-Routine Maintenance i.e. pot holes filling, repairs cracks etc.

-Periodic maintenance – periodical renewal

-Rehabilitation and strengthening etc major restoration or upgrading of the pavement.

Periodic Renewal is the main components under maintenance and the periodicity for renewal of NH, SH, MDR, ODR and VR for different range of traffic is given in clause 6.5 of IRC 82:1982. The periodicity of the renewal indicated therein should only be taken as general guidelines for the purpose of budgeting and determining the extent of renewal programme. It does not indicate the expected life.

Normally 20 mm thick premix carpet, mix seal or SDBC may also be provided depending on traffic intensity. According to Government of India guidelines in letter No RW/NH-33044/10/2000-S&R dated 26.12.2002 of Ministry of Road Transport and Highway 20 mm mixseal/20 mm PC with seal coat for low traffic road (<1500 CVD), 25 mm SDBC/BC for high traffic roads (>1500 CVD). BC shall be laid only where the existing surface has BC as wearing course shall be adopted.

Audit Approach:

It was noticed that for periodical renewal 40 mm thick BC was provided instead of 25 mm thick. This involved extra pavement thickness. Similarly in special repair work besides profile corrective course (PCC) and wearing courses, a layer of BM/DBM was laid which was not warranted and supported by test report.

FOOT PATH AND KERBS

According to clause 7.2 of IRC specifications for Geometric Design standards for urban roads in plan (IRC 86:1983) barrier type kerbs of size 325x115x165 mm and mountable type of kerb of size 200x50x250 mm were to be adopted for foot path having pedestrian traffic and for median respectively. The barrier type of kerbs with a height of 325 mm should be buried to a depth of 125 mm below the top level of pavement of the road and the mountable type of kerbs with a height of 200 mm should be buried to a depth of 100 mm.

Audit Approach:

To see whether the prescribed size of kerb was used or higher size adopted resulting in extra cost due to adoption of higher size.

1.2 BRIDGES

Bridge is a structure having a total length of above 6 metres between the inner faces of the dirt walls for carrying traffic on road or railway. The bridges shall be classified as minor bridge and major bridge.

Minor bridge – Bridge having a total length upto 60 metres. Clause 101.1 of IRC 5:1998

Major bridge – Bridge having a total length above 60 metres.

The bridges are designed and constructed adopting the following IRC specifications.

IRC 5:1998	Standard specification and code of practice for road bridges- Section I general features of design
IRC 6:1966	Standard specification and code of practice for road bridges – Section II load and stress
IRC 21:1987	Standard specification and code of practice for road bridges- Section III cement concrete
IRC 40 : 1995	Standard specification and code of practice for road bridges- Section IV (bricks, stones and masonry)
IRC 22:1986	Standard specification and code of practice for road bridges- Section VI composite construction
IRC 78:1983	Standard specification and code of practice for road bridges- Section VII formation and sub structure
IRC 83:1987	Standard specification and code of practice for road bridges- Section IX bearings
IRC SP:20 2002	Rural Road Manual
IRC SP 13:2001	Guideline for the design of small bridges and culvert

1. Component of Bridge

The component of the bridge is broadly grouped into

i) Foundation
ii) Substructure
iii) Superstructure

The foundation are different type viz., open foundation, well foundation, raft foundation and pile foundation. The substructure is the portion of the bridge structure such as pier and abutments above the foundation unit and supporting the superstructure. It shall also include returns and wing walls but exclude bearings.

Superstructure is the portion of bridge structure above the substructure level viz., deckslab/beam, hand rail, foot path etc.

2. Definition

Clearance: Is the shortest distance between the boundaries at a specified position of a bridge.

Free Board: Free board at any point is the difference between the highest flood level after allowing for afflux if any, and the formation level of road embankment on the approaches or top level of guide bunds at that point. Free Board for highlevel bridge shall in no case be less than 600 mm

Linear Water way: is the width of waterway between the extreme edge of water surface at the highest flood level measured at right angles to the abutment faces.

Effective Linear Water way: is the total width of the waterway of the bridge at HFL minus the effective width of obstruction.

Afflux: The rise in flood level of the river immediately on the upsteam of the bridge as a result of obstruction to the natural flow caused by the construction of bridge and its approaches.

Scour Depth: In natural stream, the scouring action of the current is not uniform all along the bed width particularly at the bends and also round obstructions to the flow eg. The piers of bridges there is deeper scour than normal. The assessment of the scour depth is relevant for the design of bridge foundations and protective works. Whenever possible such assessment should be based on data made available from actual sounding taken at the proposed bridge site or in its vicinity. Such soundings are being taken during immediately after a flood before the scour holes have had time to silt up appreciably. Necessary allowance shall be made in the observed scour depth for increased depth for various reasons.

Vertical clearance: Adequate vertical clearance shall be provided in case of all high level bridges which is usually the height from the designed HFL with afflux to the lowest point of the bridge superstructure. Such clearance shall be allowed as follows.

Discharge in cu.meters	Minimum vertical clearance in mm
Upto 0.3	150
Above 0.3 and upto 3	450
Above 3 and upto 30	600
Above 30 and upto300	900
Above 300 and upto 3000	1200
Above 3000	1500

The minimum clearance shall be measured from the lowest point of deck structure inclusive of main girders in the central half of the clear opening unless otherwise specified.

In case of slab bridges the difference between deck level and affluxed HFL shall not be less than 1.75 m.

3. Determination of design discharge (clause 103 of IRC 5 1998)

The length of the bridge required to be constructed is primarily based on design discharge.

- shall be maximum flood discharge of 50 years return cycle. If the data is not available it will be determined by the following method.
  i) From the record available discharge observed in the stream at the site.

ii) From rain fall and other characteristic of the Catchment – using empirical formula applicable to that region or by a recognized method.
iii) By area velocity method.
iv) By unit hydrograph method.

Wherever possible more than one method shall be adopted, results compared and the maximum discharge fixed by judgement by the engineer responsible for the design.

- Based on the design discharge the linear waterway and effective linear waterway of the bridge will be designed on the basis of clause 104 of IRC 5:1998.

- Similarly the width of carriage way (between the outermost faces of the bridge) footpath and median are also designed as per clause 112 of IRC 5:1998.
  - For minor bridge, the width of the bridge shall be equal to the full formation width of the approaches subject to the minimum of 10 metres for the hill road/ODR and 12 metres for the other roads.

  - For 2 lane bridges having total length more than 60 metres in non-urban area, the width of the bridge shall be 7.5 metres carriageway plus 1.5 metres wide footpath on either side wherever required.

  - For 2 lane bridges having total length more than 60 metres in urban area it shall be equal to full formation width of the approaches.

  - For multilane bridges, in both urban and non-urban areas the overall width shall be same as the full formation width of the approaches. Wherever footpaths are provided the width shall not be less than 1.5 metres. The width of the median in the bridge portion shall be kept same as that in the approaches.

4. Culverts and small bridges in Rural Roads (IRC SP:20-2002)

- Apply to all minor bridges in village roads and ODR having traffic intensity of less than 450 CVPD.

Overall width of CD works
Clause 7.2.1. of IRC SP 20-2002

Type of cross drainage forms	For 7.5 m roadway width		For 6 m roadway width	
	Overall width (m)	Carriage way (m)	Overall width (m)	Carriage way (m)

Culvert	7.5	6.6	6	5.5
Small and minor bridges	6.4	5.5	6	5.5
Submersible bridges	7.5	6.6	6	5.5

5. construction of small bridges and culvert in road other than Rural Road

(IRC SP 13:2001)

- Applies to all road NH, SH, MDR, ODR except those covered by IRC SP 20-2002

- Culvert: A bridge having a gross length of 6 m between inner faces of abutment. As per current practice culverts are designated as 2,3,4,5 and 6 m slabs culvert or 1000 mm single to 6 rows pipe culvert etc. In all these cases clear linear water way is less than 6 m.
  - Small bridge: A bridge where the span is more than 6 m and where overall length of the bridge between centers of and support at abutment is 30 m.
  - Submersible bridge: is a bridge designed to be overtopped in floods It is advisable to provide at rural roads & ODRs due to interruption at submergence during flood and constructed on economic ground.
  - High level bridge: is a bridge which carries the roadway above the highest flood level of the river.
  - The overall widths adopted for culverts and small bridges are for 2 lane carriageway

  NH & SH = 12 m
  MDR = 8.4 m
  Rural roads = 6.0 m

6. Fixation of span Arrangements and selection of type of structure – (Para 4.7, IRC pocket book for Bridge Engineer)

Each site provide its own peculiar conditions affecting the choice of the type of bridge affecting maximum efficiency, permanency and economy. Generally, it will be found that for most sites several alternative span arrangement and the type structure will depend on several factors such as site characteristics, type of sub soil strata, height and length of the bridge, design capability, availability of construction material, labour etc. Generally the aim should be to provide for as few spans as possible, since the construction of foundations often takes the major portion of construction cost and time apart from obstructing the flow. Considering the variable items the cost of super

structure increases and of sub structure decreases with an increase in the span length. As a rough guide, the most economical span length is one in which the cost of variable items of the superstructure equals the cost of sub structure and foundations. In actual practice, however this ideal conditions is seldom achieved and it would be necessary to evaluate the cost of alternative arrangement and then choose the one which leads to an overall minimum cost of constructions and early completion.

For small structures with open foundations and soiled abutments and piers rough guide for the economical span length is

a) for masonry arch bridges S= 2h

b) for RCC slab bridges S=1.5 h

where S = clear span length in metre

h = total height of abutment or pier from the bottom of its foundation to its top in metre, for arch bridges it is measured from foundation to the intrados of the key stone.

The design report is an important parameter for selecting the span arrangements. Eventhough a normal analysis may indicate the adoption of a particular span arrangement, after call of tenders it is often been that the span selected by the successful tenderer is different and often governed by available materials and design capability for the said arrangement. Such tender data should be utilized in updating the cost analysis of bridges needed for future case. Normally for bridges with 7.5 m carriageway and 1.5 metre wide footpath the following limitations of span length are generally in use.

The ranges of span length within which a particular type of superstructure can be economical along with other considerations like type of foundations etc., are given below:

(Key: Para 5.7.4 – IRC SP 54-2000)

	Type of superstructure	Span length
1	RCC single or multiple boxes	1.5 to 15 m
2	Simply supported RCC slabs	3 to 10 m
3	Simply supported RCC T Beam	10 to 25 m
4	Simply supported PSC girder bridges	25 to 45 m
5	Simply supported RCC voided slabs	10 to 15 m

6	Continuous RCC voided slabs	10 to 20 m
7	Continuous PSC voided slabs	15 to 30 m
8	RCC box sections , simply supported/balanced cantilever continuous	25 to 50 m
9	PSC box sections simply supported balanced cantilever	35 to 75 m
10	PSC cantilever constructions/continuous	75 to 150 m
11	Cable stayed bridge	200 to 500 m
12	Suspension bridges	500 m onwards

- However, whenever an economical span arrangement and type of structure is decided, it has to be ensured that the required infrastructural facilities, design and construction capabilities, specialized materials etc are available.

7. Type, depth and design of Foundations:

- The selection of the type of foundation is usually based on the soil condition, cross section details of the channel type of founding strata underlying the bed, design scour depth as determined from the investigation. The detailed design should be carried out following the guidelines given in the design philosophy. Computer aided design methods are to be resorted to.

Audit Approach

- ***The above provision are only general information to understand the design and construction aspects of bridge works. It is too technical to an audit point of view but still offers a scope for audit in design and construction aspect. The following are some of the audit approaches.***
- ***Where bridges were constructed to 8.5 m/10.5 m width ODR having traffic intensity less than 450 CVPD was noticed. According to clause 7.2.1 of IRC SP 20:2002, over width of small and minor bridges constructed in rural road with roadway width of 7.5 m is to have overall bridge width of 6.4 m and carriageway width of 5.5 m only. The excess width of bridge construction has to be commented. To an audit query, the Chief Engineer (H), Design and Investigation stated (on 28.6.2002) that the approximate percentage of increase in running meter cost for the provision of foot path in the bridges will be 28% to 25%. The running metre rate depends on span length, height of substructure, Superstructure and type of foundation and***

vary from bridge to bridge. Hence approximate minimum increase is adopted at 25% per metre. Adopting this percentage of increase, the extra cost for the bridge position and approaches are to be worked out.

The provision of foot path is contemplated in urban roads for free movement of pedestrians and could be constructed if 1200 persons per hour is expected to use it. The CE(H) D&I also confirmed (February 2002) that foot path were provided in bridges constructed within the built up area. But foot path was also constructed in rural roads. This may also be analysed and commented as above.

(e.g) ***The roads in rural areas with 7.5 m width and 3.5 m carriageway will require 8.5 metres width bridge without foot path. 13 bridges were constructed with foot path involving additional expenditure of Rs 8.92 crores.***

- ***IRC 5:1998 specifications provided for designing bridge for waterways based on the designed discharges and specified the formula for arriving at designed discharge, linear water ways (LW) and effective linear water way (ELW). But during design and construction, ELW was inflated in many cases leading to greater length of bridge than required for. Audit should compare the LW and ELW actually calculated for the design charge adopted, bed width of the river, LW of existing bridge, existing railway bridge/bridges in the same river in down stream/upstream and compare them to arrive at probable maximum length of the bridge. The extra cost may be calculated for substructure position and foundation position separately for the extra length of the bridge work affecting superstructure foundation and substructure.***

3. OTHER POINTS IMPORTANT ON HIGHWAYS

1**. Collection of Toll Fee :**

- According to orders of Government in G.O.Ms.No. 769 PWD dated 13.3.65, G.O.Ms.No. 928, Transport dated 11.8.89 read with Gazette Notification dated 18.7.1997, toll would be levied in case of any road or bridge made, improved or repaired at a cost of Rs 25 lakh and above

till the cost of construction is recouped. The proceeds from the levy of toll should be credited to the revenue of the Government. According to Para 507 of Highways Manual Vol.IV, proposals for levy of toll have to be submitted by the department to the Government for approval atleast three months in advance of probable date of completion of the bridge. The collection of toll should be effected through Revenue Department from the date of opening of the bridge for traffic on approval of the Government. However with a view to bringing the qualifying cost of bridges for levy of toll on par with those constructed on NH roads, a proposal was forwarded (October 1995) to the Government by the CE(H) for enhancement of monetary limit for levy of toll on bridges from Rs 25 lakh to Rs 100 lakh.

- In D.O letter No 36293 Finance/2001-1 dated 14.5.2001, the Secretary to Government Finance Department addressed to Secretary to Government, Highways Department instructed to collect tolls from the users of bridge constructed at a cost of Rs 1 crore and above as per Madras Roads and Bridges Toll Rules 1942 framed under the Indian Tolls Act 1851 read with G.O.Ms.No. 928 Transport dated 16.8.1989, and the proposal made by CE for enhancement of the monetary limit.
- In D.O letter No. 120&65/HN 2/91-36 Highways dated 17.8.2001 the Secretary to Government, had also requested the CE to explore the possibility of collecting toll for bridges constructed at a cost of Rs 25 lakh.

2. Re-imbursement of Railway share in construction of ROB/RUB

- The work of construction of ROB/RUB in lieu of existing level crossing on Government road is executed under Railway Work Programme. The cost of construction of ROB/RUB including approaches restricted to 2 lane road with foot path in urban town and 2 lane in other places including approaches diversion road, shifting sewer, water main, cable etc excluding cost of land acquisition and light arrangements are shared by Railways and State on 50:50.

- But cases are available where the Highways Department had failed to prepare the completion report and get reimbursement of the Railway share, due to inclusion of non-eligible items of work, in the demand, delay in raising demand, failure/delay in furnishing clarification sought for by Railways in time.
- According to the norms and conditions for reimbursement of railway share for ROB/RUB, the existing level crossing had to be closed after construction of ROB. Case are available where the level crossing was not closed by Highways and the Railway had not reimbursed the cost.
- Government of India, Ministry of Railways, had also constituted Railway Safety Work Funds (RSWF) in 1966 to render assistance to the state Government in financing safety works such as manning/upgradation of existing level crossing or their replacement by ROB/RUB. 80% of the fund was released to states and 20% retained by railways. But Government of Tamil Nadu had not availed of the fund. In the meeting held on 24th November 1997, at the chamber of Secretary to Government, the Railway authorities pointed out that while other State Government were claiming reimbursement of expenditure from the RSWF, Tamil Nadu State had alone not claimed it so far. At the direction of Secretary to Government, in November 2000, the CE(H) preferred (September 2001) claim for reimbursement of expenditure incurred already under RSWF.

While auditing the transactions of the office CE(H) General, CE(H) Project I it may be examined to ensure prompt system for raising of demand pursuance thereof are available. Comments on non recovery, delay defective preparation of claim etc may be examined.

3. CONTRIBUTION RECOVERABLE FROM THE MUNICIPAL COUNCIL

According to para 194(1) of the Tamil Nadu Highways Manual Vol.IV, contribution are recoverable from the Municipalities for the works carried out by the Highways departments at 26.875 percent of the works outlay inclusive of centage charge

for improvement works including bridge works on Government roads other than NH in Municipal.

Works executed in Municipal areas have to be examined and commented for non-recovery of contribution.

4. Deposit Works

According to Para 193 of Tamill Nadu Highway Manual Vol.IV, contribution towards works under taken as 'deposit works' should be realised before any liability is incurred on account of the work. But the department failed to adhere to the codal provision in many cases and incurred expenditure on deposits work more than the amount deposited by diversion if found. Cases of non-recovery over deposit amount, delay etc maybe analysed.

5. Road cut restoration charge

The service departments such as telecom, telephone, Electricity Board, TWAD board etc are remitting the road cut restoration charges towards road cutting and restoration cost to the extent of damages on road cut in highway road. The restoration charges are assessed by the Highway Department and collected from service department and remitted under "8443 – Civil Deposit". This amount was kept in the deposit account with the intention of restoring the damages by road cut immediately by treating them as 'Deposit' works. However, in practice, the department had not executed the work to the extent to which originally assessed and also in the roads for which the amount was collected. Hence there were heavy accumulation in 'Deposit' head. This accumulated fund was being misused by the departmental officers for other works by obtaining LOC. The Legislature has no control over the expenditure incurred from the deposit.

According to Government of India guidelines in circular No. RW/NH-33044/17/2000/S&R Ministry of Surface Transport dated 29.9.2000, the road cut restoration charges are treated as other receipts and when collected credited to Revenue head of account viz "1054 Roads and Bridges" – other receipt.

Treating the road cut restoration charges as other receipt maybe insisted upon by audit besides comments made on diversion of the deposit amount to works other than those work for which road cut restoration charge was collected.

6. Road cut Restoration work :

(Technical circular – memo No.S-29-2-1 AE(B&E) dated 28.6.2001 of Highways Research Station, Chennai)

i) Restoration of cut in pavement/hard/paved shoulder/earthern shoulder should be provided with bed cushion of 30 cm, side fills of 20 cm on either side and top cushion provided with coarse river sand; above the 20 cm thick 1:3:6 cement concrete provided. In respect of pavement and paved shoulder, a bituminous wearing course in conformity of adjoining pavement may also be provided.

In rural areas a bed cushion of 30 cm and side fill of 20 cm on either side and top cushion provided with coarse river sand above this 15 cm thick gravel or sand gravel layer provided.

If sufficient space is available in embankment and side drains are not available trench may be dug at a distance of 1 m from toe, and in case of side drain it may 1m from the side drain.

7. Payment of shifting charges

- While carrying out improvements works and widening of roads and construction of bridge, the service utilities such as cable, pole, line etc belonging to TNEB, Telecommunication Department, water main, service mains of local bodies and TWAD were required to be shifted. To shift the service utilities, Highways Department used to pay advance for service department and failed to recover the advance even though service department were required to bear the shifting charges.
- According to G.O.MS.No. 1525 PWD dated 30.7.1984, whenever the Highways proposes to widen a road and the proposal involved shifting of cables, lines, poles etc belonging to the TNEB, a joint inspection of the officials of Board and Highway Department should be made and if it is agreed to shift the electricity lines, poles, cables etc. the expenditure thereon should be borne by the TNEB. If there was difference of opinion in the matter between the officials of TNEB and Highways the matter should be decided by the Government. Government in Energy Department also further examined the request of TNEB to meet the expenses on shifting of electric pole, cable etc by

the intending department like Highways and ordered in G.O.MS.No. 101 Energy (C3) dated 18.12.2001 that the entire cost of shifting of electric pole, cable etc. on account of widening the road, etc should be borne by TNEB only since TNEB is collecting the electric current consumption charge from the public, Industries, commercial Institutions etc. But Highways department had made advance payment to TNEB towards shifting charges either under orders of Government or CE/SE, but failed to recover the advances. Instead, the advances were adjusted against the shifting charges. Comments on failure to recover the shifting charges and long pending advances without adjustment after shifting may be made.

- According to section 10,12,13 & 14 of the Indian Telegraphs Act 1885, the Telecommunication Department was required to bear the shifting charges. But the advance made to Telephone, Telegraph Department were adjusted against shifting charges contrary to the provision of the Act.

8. Seigniorage charge

Tamil Nadu mines and Mineral concession Rules 1959 stipulates that seigniorage fee was to be payable for extraction of minor minerals (viz earth, gravel, sand, rough stone, broken metal etc) from Government land or even from Putta land. The District Collector would accord permission to extract those minor mineral subject to the condition specified by the District Collector in the permit and one of those condition is that seigniorage fee had to be paid for the actual quantity extracted at the stipulated rate. But such recovery of seigniorage fee was exempted in case if the estimate prepared did not include cost of the material and that exemption was allowed on specific certificate furnished by the user department. The seigniorage fee prescribed by Government in G.O.MS.No. 91 Industries (MMC 1) dated 23.10.2002 (effective from 1.11.2002) is given below:

Sl.No	Name of Mineral	Percent land upto 10 cubic feet	Rate per cubic metre
1	Rough stone and boulders	6.50	-
2	Broken stone, metal, jelly etc	9.00	-

3	Laterites	4.50	-
4	Granite – Dolerite type	-	2500
5	Granite – other type	-	1500
6	Ordinary sand	8.50	-
7	Earth	4.00	-
8	Lime stone, Lime cell etc.	20	-
9	Pebbles and nodules	30	-
10	Stealite and other stone for use to make household utensils and carving	8	-
11	All other minor mineral	20% of market value	-

Note : 1 cuft = 0.0283 m^3

Audit Approach:

Though estimate included cost of materials, the DE/EE very often certify to the District Collector that the cost of materials was not included in the estimate and that District Collector exempt the seigniorage fee. Besides the quoted rate included cost materials also as it was included in the estimate.

With the same permit contracts would lift large quantity without paying seigniorage fee. But received payment for the entire quantity of work done. Hence the quantity of work on which seigniorage fee payable has to be compared with quantity for which seigniorage fee paid to Revenue Department.(i.e theoretical requirement compared with the payment quantity)

(e.g) DE, Project I Madurai obtained permission from Collector for extraction of earth and gravel from PWD tank. The contractor paid seigniorage fee for only 5140 m^3 of earth and gravel but extracted 5.95 lakh m^3 for which a fee of Rs 63.08 lakh m^3 is payable which was not recovered from the contractor.

The above involved unintended benefit to the contractors.

9. Contractor ledger

According to Para 153 and 154 of Account Code Vol III, an account of each contractor/supplier had to be maintained in ledger accounts and the balance has to be examined periodically to ensure that balances did not remain outstanding for a long period without justification.

10. Application of Seal Coat

At present seal coat type A is being adopted for execution in the field. Seal coat type B being a premix material is easier to work with. Traffic may be allowed on seal coat type B, surface soon after final rolling when the premix cooled down to the

surrounding temperature. The Director of Highway Research Station suggested that the application of seal coat type B (a premix seal) over premix carpet maybe adopted for better performance in the field in place of seal coat type A.

(vide Director HRS letter BIT/HRS/Seal coat – 1/2000 dated 6.12.2000)

Seal coat type B is comparatively cheaper and the composition of seal coat type A and Type B are as under per 10 m^2

	Seal type A	Seal cost type B
Bitumen	9.8 Kg	6.8 Kg
Stone chips 6.7 mm	.09 m^3	--
Sand or quarry dust	--	0.06 m^3

11. Use of conventional bitumen 80/100 for Tack coat

Taking into consideration the failure of bituminous surfacing like SDBC and BM, the Board of Engineers in its 5815 meeting held on 29.4.2004 decided to use bitumen grade 80/100 for tack coat as per quantity specified in clause 502.3.2 of MOST specifications (First Revision) i.e. In memo No 63942/2002/Salai 2 dated 24.5.2004, the CE(H) General, Chennai instructed to use 80/100 grade bitumen for tack coat over BT and WBM surface as specified in clause 502 3.2 of MOST specification 1978 in the estimates to be sanctioned in future.

3. GENERAL TOPICS

3.1 TENDERING SYSTEM

1. General Principle

According to the Tamil Nadu Transparency in Tender Act 1998 and rules made there under the following methods of tendering adopted:

i) Piece work contract

ii) Lump sum contract

iii) Turnkey contract

iv) Multi stage contracting including pre-qualification and two cover system

v) Fixed rate Contract

- Percentage tender system originally listed for maintenance work valued Rs.1 lakh has been extended for other works to monetary limit upto Rs.20 lakh in Highways vide G.O.Ms.No.21 Highways dated 25.1.99—unless a

standard schedule of rate commensurating the market rate with periodical updation exists, the percentage tender system may not be a rational tendering

- Turnkey contract stipulates for entrustment of work/service in toto to a single and prime contractor. The entire process of investigation, project formulation, planning and designs, evolving specifications, construction, erection-testing and commissioning. **(vide G.O.Ms.No.114 P & AR (O&M) dt.30.3.92)**

- According to Para 156(1)(g) and Note there under of Tamil Nadu Highways Manual Vol. IV, the tender notice for major bridge works costing more than Rs.50 lakh includes a clause that the contractor may submit alternative design with quotation for the complete work, complete set of drawings estimates along with detailed calculation so that the alternative design can be fully and quickly examined. This monetary limit was raised to Rs.1 Crore in G.O.Ms.No.490 Finance (Salaries) dated 17.9.98 and further raised to Rs.5 Crore by Highways Department in G.O.Ms.No. 21 Highways (HN 1) dated 25.1.1999.

- Tamil Nadu Transparency in Tender Act 1998 stipulates works with value exceeding Rs.1 Crore pre-qualification has to be done with reference to the eligibility criteria laid down so as to ensure that eligible and viable contractors participated in the tender and also to eliminate the double cover system. Prequalification will be based on meeting all the minimum criteria regarding the applicants general and particular experience, personal and equipment capabilities and financial position as demonstrated by the bidder stipulated in the prequalification bid document. After evaluation of prequalification, tenders will be called for from the evaluated prequalified bidder.

- Under two cover system, the bidders were required to submit the technical bid and financial bid simultaneously on the due date. After evaluation

of technical bid financial bid will be opened for the bidders whose technical bid was found to be viable.

- Ibid Act also stipulates for inclusion of price variation clause for works involving time schedule of more than 18 months.

- Law of Contract stipulates that the contract concludes on the acceptance of the bid, the bid documents did not provide specific clause for recovery of additional expenditure incurred in case of withdrawal of tender after acceptance. Clause 104.05 of PS to SSRB stipulates if the successful bidder fails to sign the agreement, his tender will be considered just as a cause of annulment of award and forfeiture of EMD to Government not as a penalty—As per Contract Act, a valid contract emerges on receipt of written communication of acceptance of tender. But though the law of contract stipulate that the contract emerged on the acceptance of the bid, the bid documents did not provide for relief by way of recovery of extra cost if there was withdrawal of tender after acceptance in all cases. These aspects also be looked into.

2. Reduction of high pitched tenders:

In G.O.Mos.No.445 PWD(HN 1) dated 26.2.1990, Government allow the tenders inviting authorities to negotiate only with the lowest tenderer to the advantage of the Government. If the negotiations with the lowest tenderer fail, then the tender should be legally and literally closed and retender ordered.

In letter No.42652 HN / 90-1 PWD dated 30.1.91, Government also clarified that the G.O. in question is only an enabling provision so as to enable the competent authorities to negotiate with the lowest valid tenderer to the advantage of the Government and it does not mean that if the lowest tenderer does not agree to reduce any of his rates, the tender should be rejected on that count alone if the same is found to be otherwise acceptable.

3. Cartel formation:

In D.O lr.No 4801/HM/97-1 Highways dated 24.3.1997 Government laid certain guidelines for openness and transparency in tender. They are

(i) The process of tender for entrustment of works shall have crystal clear transparency and total openness with a view to primarily avoid all possible irregularities and ultimately to nullify consequential loss to Government exchequer.

(ii) The intension of Government aimed to attract more and more contractors for work has not made a good take of due to formation of rings among contractors for obvious reasons or sort of consortium among themselves which otherwise is to benefit the contractors. This may be due to under estimate prepared for such works or due to unrealistic elements prescribed in the tender norms or due to any technical flaw in the opinion of contractors. As such very practical approach feasible for the field conditions should be worked out in a way to weed out all negative aspects of contractors and the tender process be made very clear and attractive so that many contractors as possible may come forward for participation in the open tender system.

(iii) Intensified efforts should be taken to identify the 'black-sheep' among contractors and to sideline them as such contractors are always in the habit of forming combination groups or rings of their own to boost the estimate in their schedule application forms aiming to derive more benefits in their favour and defeating the very purpose of Government intension.

(iv) There should be no room for complaints from any quarter on non-issue or non-availability of tender forms to contractors and in fact sufficient number of contractors should be allowed to participate in the tender offer.

(v) If no efforts are taken to attract more number of contractors, it will indirectly encourage the limited number of usual contractors to get the tender work at their choice. This will in turn help the restoration of the old single tender system encouraged in the past and this should therefore be discouraged at any cost to keep the decision of the Government alive and to achieve the intended objective.

(vi) G.O.Ms.No. 222 PWD dated 8.4.99 read with G.O.Ms.No. 446 Finance salaries dated 26.9.2000 prescribes the procedure for giving wide publicity for the NITs in leading Newspapers in Tamil and English, sending copies of NITs to the offices of BDO, District collector within which the tender issuing office is located for

display in the respective offices whether wide public is given and according to G.O.Ms.No. 1789 PWD dated 29.12.2002 the EE shall send a performance report in respect of contractors to the SE after reviewing the contractors register annually and action taken to remove such of those contractors who have not tendered for last two years and who have failed to execute the work. It may be seen that the annual review of contractors register are ordered by Government was carried out or not. Failure to do so would lead to poor participation of tender which will lead for cartel formation.

4. Delay in Acceptance of tender:

- In G.O.Ms.No. 873 PWD dated 4.5.1982, Government prescribed time schedule for evaluation and acceptance of the tender as detailed below:

Level of process	Time schedule	Remark
SE to CE	15 days	Including negotiation period
CE to Government	7 days	
Government	1 month	Including duration for approval by tender committee

- Again in G.O.Ms.No. 490 Finance (Salaries) dated 11.9.1998, Government reiterated the time schedule prescribed above with the modification that orders of tender acceptance would be issued at Government level within 15 days and the agreement should be signed within 15 days of receipt of tender acceptance order.
- In office memorandum F.No. 3(2)/95-PMU (Pt files) Government of India, Department of Economic Affairs, Government of India streamlined the procurement procedures fixing time frame for World Bank aided projects in India as detailed below.

(i) Evaluation of bids for prequalification for works as well as evaluation of bid for procurement of works is to be completed within 30 days and 45 days respectively fro m the date of bid opening.

(ii) 30 days was prescribed for obtaining the approval of the evaluated bids by the competent authority and recommendation for award of work after receipt of evaluation of bids.

(iii) Issue of letter of award should be done within 15 days from the date of receipt of concurrence from the Bank.

(iv) Banks NOC to bid documents as well as concurrence to the evaluation/recommendation to the award fixed at 14-20 days.

(v) Similarly completion of evaluation of bids for procurement of goods including approval of competent authority and its forwarding to the Bank was kept as 45 days – 60 days for bid validity within 90 days, 90 days for bid validity of 120 days and 120 days for bid validity of 180 days. Completion of evaluation of bid for procurement of supply and erection equipment including approval of the competent authority should be made within 120 days after bid opening.

(vi) The NIT should be published in Indian Trade Journal where the value exceeds Rs 10 crores.

(vii) In the case of purchase of goods where the quantity offered at the lowest price is less than the total quantity required, the Tender accepting authority may after placing orders with the lowest tender for the entire quantity offered by him, adopt either or both the following procedure to procure the balance quantity.

(1) Negotiate with the next lowest tenderer in strict ascending order of evaluated price and require them to match the price offered by the lowest tenderer and place orders untill the entire quantity required is ordered or
(2) Require all the other eligible tenderers who participated in the tender and offered a price higher than the lowest tenderer to submit sealed offer of the quantity they will be willing to supply at the price quoted by the lowest evaluated tenderer and thereafter place orders for the remaining required quantity with all those who match the lowest evaluated price such that those who quoted lower prices in the original tender get a higher priority for supply.

(3) In case if the bidders other than the lowest evaluated bidder fail to agree to accept the lowest price or the total quantity offered by them at the price quoted by him, is less than the required quantity, the Tender Accepting authority may place orders for the remaining quantity at different rates with different suppliers in the ascending orders of evaluated price until the entire quantity required is covered.

Provided that where different quantities have to be procured at more than one price from one or more tenderers, the Tender Accepting authority may decide not to procure beyond a price considered economical although the entire quantity originally stated to be required in tender document is not ordered.

Audit Approach

The delay in finalisation of tender after bid validity period would cause:

- ***Extra cost due to price variation for the period of delay if price variation clause was available in that particular contract.***
- ***In case the lowest contractor backed out immediately after the validity period of tender, the department had either to accept the next tender or to invite fresh tender which would involve extra cost.***

- ***Alternative design approved and entrusted to the contractors had to be checked with the actual quantity on each item of work executed at site, recorded in the M.Book for final bill with the quantities of various item of work specified by the contractors in the tender document and arrived the contract value. Cases were often noticed that actual quantity of work done at site was much lesser than the quantity of work on each item of work indicated in the tender schedule for alternative design which was required to be furnished by the bidder. But the department failed to check the quantity on various items of work. The agreement provided for fixed contract payment at each stage of completion of work without reference to quantity. Consequently the contractors were paid extra over the actual value of work done at site.***

(e.g) For the scheme of construction of 106 bridges on turnkey basis, the CE adopted the bill of quantities of the lowest tenderer for execution, without verifying the correctness of the quantities for preparation of

estimates. It was seen that the actual quantities extended was far less than the BOQ for which payments were made. Thus there was unintended benefit to the contractor by inflation of BOQ (money value 11.06 crore)

- ***In percentage tender audit risk is high. The contractor had to quote a percentage on the estimate cost of the work and are paid accordingly. In case if there is any error in preparation of the cost estimate it would automatically reflect on the payment to the contractors.***

(e.g) According to the model standard data for road works approved by Board of Engineers and Communicated to the field office by the CE, in the year 1996, the daily out turn for water sprinkler for formation of sub base with sand gravel mix was 1000 cum. Whereas in many cases, the daily out turn of water prinkler was adopted at 1000 sq.m. This resulted in increase in cost of SG mix by Rs 15.30/cum.

Similar points would emanate on scrutiny of the estimate with data which is vital factor as percentage tender.

3.2 PRICE VARIATION:

1. General Principle

According to Tamil Nadu Transparency in tender Act 1998 and Rule 14 (8) of Tamil Nadu Transparency in Tender Rules 2000, price variation clause would be provided in the tender for works involving time schedule for completion with a time limit of more than 18months. Similarly all the externally aided project (viz World Bank ADB JBIC etc) price variation clause is included in the contract for the work involving time schedule of more than 18 months. Price variation is payment due to increase/decrease in price/wage after receipt of tender for the work. The contract price shall be adjusted for increase or decrease in the rate and price for labour, materials, fuel and lubricants in accordance with following principal and procedure and as per formula given below and also in the contract.

i) The base date for working out such escalation shall be the last stipulated date of receipt of tender including extension, if any.

ii) Operative period of contract means the period between operative date (viz date of commencement of work if not otherwise mentioned

in the contract) and the stipulated time prescribed for completion of the work in the contract. The operative period will also include the extension of time granted on valid grounds for the reasons not attributable to the contractor.

iii) The cost of work on which escalation will be payable shall be reckoned 85% of the cost of work as per the bills, running or final, excluding any work for which payment is made at prevailing market rates. From this amount the value of materials supplied departmentally to the contractor or services rendered by the department and proposed to be recovered in the particular bill, shall be deducted before the amount of compensation for escalation is worked out. In the case of materials brought to site for which any secured advance is included in the bill, the full value of such materials as assessed by the Engineer-in-chief (and not the reduced amount for which secured advance has been paid) shall be added to the cost of work shown in the bill for operation of this clause. Similarly, when such materials are incorporated in the work and the secured advance is deducted from the bill, the full assessed value of the materials originally considered for operation of this clause should be deducted from the cost of the work shown in the bill, running or final.

iv) Components of materials, labour, POL etc shall be pre-determined for every work and incorporated in the conditions of contract attached to the tender papers included in schedule and the total of all such component should not exceed 100%. The decision of the Engineer-in-charge in working out such percentage shall be binding on the contractor.

v) The principle for calculation of the price variation is based on agreement condition. The price variations may be worked out and paid for each month or quarterly as stipulated in the agreement.

vi) The following principles shall be followed while working out the indices under consideration for calculation of price variation.

a) If the compensation for escalation is worked out at quarterly intervals and shall be with respect to the cost of work done as per bills paid during the three calendar months of the said quarter. The first such payment shall be made at the end of three months after the month (excluding) in which the tender was accepted and thereafter at three months'

interval. At the time of completion of the work, the last period for payment might become less than 3 months, depending on the actual date of completion.

b) The index relevant to any quarter/period for which such compensation is paid shall be arithmetical average of the indices relevant to the three calendar months. If the period up to date of completion after the quarter covered by the last such instalment of payment, is less than three months, the index shall be the average of the indices for the months falling within that period.

c) In case if the compensation is payable at monthly intervals, the cost of work done during the month under consideration and bills paid shall be considered and the indices shall be the indices as applicable to that month.

d) Basic index shall be indices with respect to the indices as applicable to the relevant base date or average of 3 months of the quarter immediately before the last date of the receipt of tender including the month of receipt of the tender stipulated in the contract.

vii) In the event the price of materials and/or wages of labour required for execution of the work decrease/s, there shall be a downward adjustment of the cost of work so that such price of materials and/or wages of labour shall be deductible from the cost of work under this contract and in this regard the formula prescribed in the contract shall be mutatis mutandis apply:

viii) No price variation is admissible in respect of the additional items and additional quantities work executed and paid for at mutually agreed rate derived at current schedule of rate or at such other rate mutually agreed upon.

ix) In case of reduction in the original scope of the work envisaged under the contract, the operative period shall be proportionately reduced by the Employer.

x) The payment for variation in prices shall not apply to the work carried out by the contractor beyond the stipulated time for reasons attributable to the contractor, even if time extension is allowed.

xi) In all cases, the decision of the employer with regard to the operative period shall be final and binding on the contractor.

xii) To the extent that full compensation for any rise or fall in the costs to the contractor is not covered by the provisions of this or other clauses in the contract, the

unit rate and prices included in the contract shall be deemed to include amounts to cover the contingency of such otherwise or fall in costs.

2. The price variation is calculated adopting the following formula:

Note: The wholesale price index for all commodities, steel, cement, road POL, Bitumen etc., herein after mentioned represents the indices published by the Economic Adviser to the Government of India, Ministry of Commerce and is also published in the Reserve Bank of India Bulletin.

a) Amount of price variation for General Material

$$V_1 = 0.85 \times P_0 \times K_1 \times \frac{lw_2 - lw_1}{lw_1}$$

where,

V_1 = the amount of price adjustment in rupees for general materials

P_0 = the value of work in rupees executed during the period under consideration

K_1 = a factor representing the materials (other than cement, steel and bitumen) to be arranged and supplied for all works connected with the completion of the work under this contract including all allied/ancillary/temporary works and overheads etc. as stipulated in the agreement.

lw_1 = wholesale price index for all commodities by groups and subgroups on the base date/quarter/month as stipulated in the agreement.

lw_2 = wholesale price index for all commodities during the period under consideration

b. Amount of price variation for cement

$$V_2 = 0.85 \times P_0 \times K_2 \times \frac{Cw_2 - Cw_1}{Cw_1}$$

where,

V_2 = the amount of price adjustment in rupees for cement

P_0 = the value of work in rupees executed during the period under consideration

K_2 = a factor representing the percentage of cement component for the work.

Cw_1 = Price of cement fixed by TANCEM for open market sale on the base date or the wholesale price index by group – cement on the base date/quarter/month as stipulated in the agreement

Cw_2 = Price of cement fixed by TANCEM for open market sale or the whole sale price index by group – cement during the period under consideration as stipulated in the agreement

c) Amount of Price variation for steel/rod

$$V_3 = 0.85 \text{ X } P_0 \text{ X } K_3 \text{ X } \frac{Sw_2 - Sw_1}{Sw_1}$$

where,

V_3= the amount of price adjustment in rupees for steel/rod

P_0 = the value of work in rupees executed during the period under consideration

K_3 = a factor representing the percentage of Steel/rod component for the work.

Sw_1 = Price of Steel /rod at the nearest depot of SAIL or whole sale price index by group – Steel/rod (as the base date/quarter month) as stipulated in the agreement

Sw_2 = Price of Steel/rod at the nearest depot of SAIL or whole sale price index by group – Steel/rod during the period under consideration as stipulated in the agreement.

d) Amount of Price Variation of bitumen

$$V_4 = 0.85 \text{ X } P_0 \text{ X } K_4 \text{ X } \frac{Bw_2 - Bw_1}{Bw_1}$$

where,

V_4= the amount of price adjustment in rupees for bitumen.

P_0 = the value of work in rupees executed during the period under consideration

K_4 = a factor representing the percentage of bitumen component for the work.

Bw_1 = The retail price of bitumen at the IOC depot at the nearest center or wholesale price index by group – Bitumen on the base date (on the base data/quarter month) as stipulated in the agreement

Bw_2 = the retail price of bitumen at the IOC depot at the nearest center or wholesale price index by group – Bitumen during the period under consideration as stipulated in the agreement.

e) Amount of Price variation for POL

$$V_5 = 0.85 \times P_0 \times K_5 \times \frac{D_2 - D_1}{D_1}$$

where,

V_5= the amount of price adjustment in rupees for POL

P_0 = the value of work in rupees executed during the period under consideration

K_5 = a factor representing the component of fuel and lubricants for the entire completion of the work.

D_1 = Price per litre of diesel oil base at the nearest consumer pump of IOC or whole sale price per group (Fuel, power, lubricants etc) on the base date/month/quarter as stipulated in the agreement.

D_2 = Price per litre of diesel oil pump of IOC or whole sale price per group (Fuel, power, lubricants etc) during the period under consideration.

f) Amount of variation for Labour

$$V_6 = 0.85 \times P_0 \times K_6 \times \frac{Lc_2 - Lc_1}{Lc_1}$$

where,

V_6= the amount of price adjustment in rupees for labour.

P_0 = the value of work in rupees executed during the period under consideration

K_6 = a factor representing all labour cost including benefits, amenities etc. to be incurred by the contractor for the completion of this work including all allied/ancillary/temporary works and over heads etc

Lc_1 = Consumer price index for Industrial workers at the town nearest to the site of the work, the source for such indices being Labour Bureau, Government of India and published in the Reserve Bank of India Bulletin for the base date/month/quarter as stipulated in the agreement.

Lc_2 = consumer price index for Industrial workers at the town nearest to the site of the work, the source for such indices being Labour Bureau, Government of India and published in the Reserve Bank of India Bulletin during the period under consideration.

<u>Audit Approach:</u>

- ***Cases where price variation allowed in additional item/additional quantity rate for which was allowed at current rate or agreed rate.***
- ***Cases of payment of price variation made to contractors for the extended period where extension was granted for the reason attributable to the contractor.***
- ***Cases where the full value of materials for which secured advance paid not considered.***
- ***Cases where the actual value work done during the quarter/month not considered and portion of work done earlier were carried over in the subsequent month.***
- ***Wrong adoption of indices (especially for steel or steel rod, labour indices with reference to the place of work)***

(e.g) The bid document for the scheme of 'construction of 106 bridge' provided for adjustment of contract price for increase/decrease in rate of labour, material/fuel from the last date of submission of tender. Any delay in finalisation of tender would result in payment of escalation charges. Delay in finalisation of tender in 5 packages beyond the time prescribed resulted in avoidable payment of escalation charges of Rs 1.33 crores.

2. In test checked divisions implementing the Water Resources Consolidation Projects it was seen that price variations computed and paid was erroneous due to the following reasons resulting in overpayment.

a) The actual payment made during the quarter without considering the secured advance paid and recovered during the quarter.

b) Adopting the price index of the subsequent quarter for calculating the price variation during this quarter.

c) Adopting the month end/year end All India whole sale price index instead of Average index.

d) Adopting the price index of steel instead of steel bars and rods.

e) Adopting the retail price of HSD on the date of opening the bid as base (instead of the wholesale average price index).

3.3 SUPPLEMENTAL AGREEMENTS: (ADDITIONAL ITEM AND QUANTITIES)

- Supplemental agreements shall be executed with the contractors for item involving increase or decrease of more than 25% of the total cost of the contemplated in the original agreement

(Para 105 and 106 of Highway Manual Vol.1)

- In case of work for which supplemental agreement is to be entered into during the period when the schedule of rates has not been changed from the date of execution of the original agreement then the rates for the supplemental agreement will be the prevailing schedule of rates plus or minus tender premium in case the rates cannot be derived from the item in the original agreement. In case when the schedule of rate has changed either upward or downward in the intervening period, the rate prevailing as per schedule of rates at the time of execution of supplemental item will be adopted without tender percentage plus or minus over this rate.

(G.O.Ms.No. 461 Transport dated 18.4.1983)

- Additional works which cannot be separated from the original work alone may be entrusted to with the original contractor himself without calling for tenders. If the modifications proposed after the scope of the work vary much and if the modifications proposed are such that they could be separately executed, it would be advisable to call for tenders before the work is awarded.

(Government lr.No.30671/W1-84-1 Transport dated 31.7.1984)

Powers to entrust additional item and additional quantities has to be exercised as per delegation of powers prescribed by Government from time to time.

(G.O.Ms.No. 128 Transport dated 21.1.1987)

3.4 LAND ACQUISITION

- According to Para 176 of Highways Manual Vol.IV, except in cases of emergent works such as repairs of breaches etc no work shall be started on land which is not made available to Highways Department.
- A similar provision was made for PWD. According to Para 180 of Tamil Nadu Public Works 'D' code, no work should be commenced on land which has not been made over by the responsible civil officers. As per para 166 of the TNPW 'D' code where land which is not already in possession of the Government is permanently required for

the purpose of Government it should be acquired through agency of the Land Acquisition Act.

- Acquisition of land for Highways could be made under section 15 to 25 of Tamil Nadu Highways Act 2001 which came in to force from 16.9.2002. All other cases acquisition of land has to be done under Land Acquisition Act 1894.

1. Acquisition of Land under Tamil Nadu Highways Act 2001

(Received the assent of President on 16.9.2002)

The extract of relevant provision of the ibid Act relating in acquisition is given below:

Section 15 (1): If the Government are satisfied that any land is required for the purpose of any highway or for construction of bridges, culverts, causeways or other structures thereon or for any purpose incidental or ancillary thereto, in furtherance of the objects of this Act, they may acquire such land by publishing in the Tamil Nadu Government Gazette a notice specifying the description of such land and the particular purpose for which such land is required.

(2) Before publishing a notice under sub-section (1), the Government shall call upon the owner and any other person having interest in such land to show cause within such time as may be specified in the notice, why the land should not be acquired. The Government shall also cause a public notice to be given in such manner as may be prescribed.

(3) The Government may, after considering the cause, if any, shown by the owner or other person having interest on such land, pass such an order under sub-section (1) as they may deem fit.

Section 16 (1): when a notice under sub-section (1) of section 15 is published in the Tamil Nadu Government Gazette, the land to which the said notice shall, on and from the date of such publication, vest absolutely in the Government free from all encumbrances;

Provided that if before actual possession of such land is taken by or on behalf or the Government, it appears for the Government, that the land is no more required for the purpose of this Act, the Government may, by notice published in the

Tamil Nadu Government Gazette, withdraw the land from acquisition. On the publication of such notice, the land shall revest with retrospective effect in the person from whom it was divested of on the issue of order under sub-section (1) of section 15 subject to such encumbrance, if any, as may be subsisting at that time;

Provided further that the owner and other persons interested shall be entitled to payment of an amount as determined in accordance with the provisions of section 29 for the damages, if any, suffered by them in consequence of the acquisition proceedings.

(2) where any land is vested in the Government under sub-section (1), the Government may, by order, direct any person who may be in possessions of the land to surrender or deliver possession thereof to the Collector or any person duly authorized by him in this behalf, within thirty days of the service of the order.

(3) If any person refuses or fails to comply with an order made under sub-section (2), the Collector may take possession of the land, and may for that purpose, use such force as may be necessary.

Section 17: Where any land has been acquired under this Act, the Government may use or cause to be used such land for the purpose of this Act.

Section 18: Every owner or person interested in any land acquired under this Act shall be entitled to receive and be paid and amount as hereinafter provided.

Section 19 (1) Where any land is acquired by the Government under this Act, the Government shall pay an amount for such acquisition, which shall be determined in accordance with the provisions of this section.

(2) Where the amount has ben determined by agreement between the Government and the person to whom the amount has to be paid, it shall be paid in accordance with such agreement.

(3) Where no such agreement can be reached, the Government shall refer the case to the Collector for determination of the amount to be paid for such acquisition as also the person or persons to whom such amount shall be paid;

Provided that no amount exceeding such amount as the Government may, by general or special order, specify, to be paid for such acquisition shall be determined by

the Collector without the previous approval of the Government or such officer as the Government may appoint in this behalf.

(4) Notwithstanding anything contained in sub-section (3), after the case is referred to the Collector under that sub-section, but before he has finally determined the amount, if the amount is determined by agreement between the Government and the person to whom the amount has to be paid, such amount shall be paid by the Collector in accordance with such agreement.

(5) Before finally determining the amount, the collector shall give an opportunity to every person to whom the amount has to be paid to state his case as to the amount.

(6) In determining the amount, the Collector shall be guided by the provisions contained in sections 23 and 24 and other relevant provisions of the Land Acquisition Act 1984, subject to modifications that in the said sections 23 and 24, the references to the date of publication of the declaration under section 6 of the said Act shall be construed as references to the date of publication of notice under sub-sections (2) and (1) respectively of section 15 of this Act.

(7) For the purpose of determining the amount –

(a) the Collector shall have power to require any person to deliver to him such returns and assessments as he considers necessary:

(b) the Collector shall also have power to require any person known or believed to be interested in the land to deliver to him a statement containing as far as may be practicable, the name of every other person interested in the land as co-owner mortgagee, tenant or otherwise, and the nature of such interest, and of the rents and profits, if any, received or receivable on account thereof for three years next preceding the date of the statement.

(8) Every persons required to deliver a return, assessment or statement under sub-section (7) shall be deemed to be legally bound to do so within the meaning of section 175 and Section 176 of the Indian Penal Code.

(9) The Collector may hear expert wittiness if it be necessary to do so in any particular case.

(10) The Collector or any officer authorized by him in this behalf shall be entitled to enter in and inspect any land which is subject to proceedings before him.

(11) The Collector shall dispose of every case referred to him under sub-section (3) for determination of amount as expeditiously as possible and in any case within six months from the date such reference.

(12) Where any case is referred to any Collector under sub-section (3), the Government may, at any stage by order, in writing and for reasons to be recorded therein, transfer it to any other officer, and upon such transfer, unless some special directions are given in the order, the officer to whom the case is transferred, may hear and dispose of the case from the stage at which it was transferred or the case may be heard and disposed of by him denovo.

20 (1) Any person aggrieved by the decision of the Collector, or the officer to whom the case was transferred, determining the amount may, within sixty days from the date of such decision, in so far as it affects him, by application to the Collector or the officer to whom the case was transferred, require that the matter be referred by him for the determination of the Court as defined in the Land Acquisition Act, 1894 and when any such application is made, the provisions of Part III of the said Act shall mutatis mutandis apply to further proceedings in respect thereof.

(2) The decision of the Court on such reference and subject only to such decision of the Collector determining the amount shall be final.

21 (1) Where several persons claim to be interested in the amount determined, the Collector shall determine the persons, who, in his opinion are entitled to receive the amount and the amount payable to each of them.

(2) When the amount has been determined under section 19, if any dispute arises as to the apportionment of the same or any part thereof, or as to the persons to whom the same or any part thereof is payable, the Collector may refer such dispute for the decision of the Court.

22 (1) Where the amount is determined by agreement, the Government shall pay such amount to the person or persons entitled thereto.

(2) where the amount is determined by the Collector or by any other officer under the provisions of section 19, the Government shall tender payment of the

amount determined to the persons entitled thereto according to such determination and shall pay to them unless prevented by someone or more of the contingencies mentioned in sub section (3).

(3) If the persons entitled to amount according to the decision of the Collector do not consent to receive it, or if there be no person competent to alienate the land or if there by any disputes as to the title to receive the amount, the Government shall deposit the amount so determined in the Court.

Provided further that any person admitted to be interested may receive such payment under protest as to the sufficiency of the amount.

Provided further that nothing herein contained shall affect the liability of any person, who may receive the whole or any part of any amount determined under this Chapter, to pay the same to the person lawfully entitled thereto.

23. where any amount has been deposited in court under subsection (3) of section 22, the Court may either of its own motion or on the application made by or on behalf of any party interested or claiming to be interested in such amount, order the same to be invested in such Government or other securities approved by the Government as it may think proper, and may direct the interest or other proceeds of any such investment to be accumulated and paid in such manner as will, in its opinion, give the parties interested therein the same benefit there from as they might have had from the land in respect whereof such amount has been deposited or as near thereto as may be.

24. when the amount is not paid or deposited on or before taking possession of the land, the Government shall pay the amount determined with interest thereon at the rate of nine per cent per annum from the time of so taking possession until it shall have been so paid or deposited.

25. Any officer of the Government, and person, either generally or specially authorised by the Government in this behalf, may enter into or upon any land or building with or without assistant or workmen for the purpose of

(a) making any inspection, survey, measurement, valuation or enquiry or taking levels of such land or buildings;

(b) examining works under construction and ascertaining the course of sewers and drains;

(c) digging or boring into the sub-soil;

(d) setting out boundaries and lines by placing marks and cutting trenches;

(e) doing any other thing necessary for the efficient administration of this Act;

Provided that—

(i) no such entry shall be made except between the hours of sunrise and sunset and without giving reasonable notice to the occupier, or if there be no occupier, to the owner of the land or building;

(ii) sufficient opportunity shall, in every instance, be given to enable women (if any) to withdraw from such land or building;

(iii) due regard shall always be had, so far as may be compatible with the exigencies of the purpose for which the entry is made, to the social and religious usages of the occupants of the land or building entered.

2. LAND ACQUISITION ACT UNDER 1894

Orders issued by Government under Land Acquisition Act are given below:

PER CHART for Land Acquisition

1. Under Emergency clause: Time schedule of the various stages upto passing award – 180 days (6 months) and upto submission of final check memo – 360days (12 months)

(Vide G.O.Ms.No. 1895 Revenue dated 27.8.1990)

(i) Upto Publication of sec 4(1) Notification = 95 days

(ii)Upto Publication of sec 6 Notification = 15 days

(iii) Publication under section 7, issue of notice taking possession and handing over possession = 40 days

(iv) Prior approval to award by collector/special commissioner = 30 days

Total = 180 days

2. Under ordinary clause : The time schedule upto passing award for unobjectionable cases is 336 days and for objectionable cases 391 days and upto submission of final check memo to the collector/Additional Collector/DRO, 508 days for unobjectionable cases and 563 days for objectionable cases.

(i) Upto publication of Notification under section 4(1)	: 150 days
(ii) Preparation of sub division enquiry under section 5(1)	
Publication of declaration under section 6 (a) un objectionable cases	: 110 days
(b) Objectionable cases	: 165 days
(iii) Passing award from 6 (1) Notification unobjectionable/objectionable	: 76 days
(iv) Submission of final check memorandum from passing award	: 172 days

(G.O.Ms.No. 1309 Revenue dated 26.9.1986)

3. Valuation of building: Valuation of building for cost more than Rs 2500/- has to be valued by PWD or Highways Department

(G.O.Ms.No. 2013 Revenue dated 24.9.1976)

4. Guidelines for Acquisition:

a. Administrative approval of the Administrative Department concerned should be obtained for acquiring Agricultural land.

b. Utmost care should be taken on acquisition of land from small farmers.

c. Acquisition of land belonging to scheduled caste/tribe should be avoided. Incase of necessity, prior approval of Government should be obtained for acquiring land belonging to SC/ST.

d. While sending proposal for acquisition of land belonging to temples no objection certificate from temple authority, necessity for acquisition and reason for not avoiding them, and details of other lands belonging to temple etc. are to be furnished.

(G.O.Ms.No. 363 Revenue dated 28.4.1995)

5. Procedure for acquisition of land through negotiation

- Government constituted the committee for fixing of value of land on negotiation uniformly for all departments.
- District level Committee (DLC) under Chairman of District Collector, State Level Committee (SLC) under the Chairman of Commissioner of Land Administration.

- The DLC has power to approve / negotiate price upto Rs 25 lakh and purchase the land at the cost of requisitioning department. DLC can negotiate upto 150% of the land value (i.e market value or guideline value whichever is less). The SLC had powers to approve the negotiated price excluding 20 lakhs. The maximum of which can be negotiated is equal to less than 150% of market/guideline value which ever is less. When the negotiated value is above 150% of the market value / guideline value after negotiation by DLC & SLC, this will be reported to Government through CLA for final orders.

(G.O.Ms.No. 885 Revenue Department 21.9.85)

- Whenever lands are to be acquired for Water Resources Consolidation Project, action will be initiated under land acquisition act 1894 and simultaneously negotiations will be conducted with the land owners by the Committee to fix the prices of land acceptable to both.

(G.O.Ms.No. 128 Public Works (WK) Department dated 11.2.94)

6. Acquisition of assigned land

According to rule 9(1) (iii) (b) of Tamil Nadu Land Reforms (Disposal of surplus land) Rules 1965, if any time begun the expiry of the period of 20 years the land assigned is required for public purpose, the assignment shall be modified or cancelled and the land shall be resumed by the Government. Those resumed land can be reserved under rule 13 of the Tamil Nadu Land Reforms (Disposal of surplus land) Rules 1965 for public purpose after observing formalities.

(Director of Land Reform letter No E1/3481/95 (L.Ref) dated 11.2.95 addressed to DAG(W)

7. Temple land

The requisition for sale of Temple land to other department has to be examined by the High level Committee headed by Special Commissioner HR & CE in respect of land valuing Rs 5 lakh in rural areas and Rs 10 lakh in Urban areas and that Committee has to fix the value.

(G.O.Ms.No. 177 Tamil Culture Development H & RC department dated 23.3.1999)

8. Exemption for obtaining sanction of Government for Agricultural land

Prior sanction of Government to acquire Agricultural land required for construction of bridges by Highways, Agricultural land not exceeding 1 hectare required for widening the existing road for each stretch of 5 Km and agricultural land no exceeding 1 hectare for formation of by pass road is not required.

(G.O.Ms.No. 154 Highways (HP 1) dated 7.9.2000)

9. Payment of compensation

The land acquisition officers have to make payments of compensation for the land acquisition by presenting bills at the Treasury by accounting that amount through "8782 Remittance PW III OR Item adjustable by PWD" and for eventual adjustment in the accounts of the work concerned. The practice of keeping the amount under the Personal Deposit account of the land acquisition officer has been dispensed with.

(G.O.Ms.No. 1050 Revenue dated 6.7.87 and G.O.Ms.No. 2146 Revenue dated 5.12.1989)

5. SOME USEFUL DATA

Cement adequacy 1m3 cement = 1440 kg

1.Cement Mortar mix (for $1m^3$)

	Quantity of sand (m^3)	Quantity of Cement (kgs)
CM 1:2	1	720
CM 1:3	1	480
CM 1:4	1	360
CM 1:5	1	288
CM 1:6	1	240

Note: Cement quantity for any mix can be obtained by diving the factor 1440 kg by that proportion i.e.CM 1:2 = 1440/2 = 720 kg)

2. Cement Concrete mic: (for $1m^3$)

Mix	**Metal of different size (m^3)**	**Cement mortar (m^3)**	**Cement concrete in cement mortar (kg/m^3)**
CC 1:4:10	0.9	0.45	136.80

CC 1:4:8	0.9	0.45	162.00
CC 1:5:10	0.9	0.45	129.60
CC 1:2:4	0.9	0.45	323.10
CC 1: ½ :3	0.9	0.45	430.80
CC 1:3:6	0.9	0.45	216

3. Design mix (Nominal mix)
M 100=1:3:6
M 150=1:2:4
M200 =1:1 ½ :3
M 250 = 1:1:2

1. Brick Work in various mix (for 10 M^3)

Size of brick	Number of bricks	Quantity of cement mortar m^3
19x9x9 cm	5000	2.2
19 x 9x 5.7cm	7500	2.7
9"x4 ½ x3"	3870	2.0
9 x 4 3/8 x 2 ¾	4350	2.5
8 ¾ x4 ¼ x 2''	6570	3.0
8 ¾ x 4 ¼ 2 ¾	4590	2.5
8 ¾ x 4 ¼ x2 ¼	6010	2.8

5. Stone Masonary (for 1m^3)

Type of stone masonary	Stone required	Mortar
Cut stone	Cut stone 1 m^3	0.16 m^3
Coursed rubble masonary Ist sort	Stone 1.1 m^3	0.28 m^3
Coursed rubble masonary II nd sort	Stone 1.1 m^3	0.32 m^3
Randum rubble masonary	Rough stone 1 m3 Bond stone 0.1 m^3	0.34 m^3

Note: 38% of mortar shall be adopted in the data for RR masonary for construction of dams and appurtenants works. Individual cases and if warranted, the above percentage limit can be raised upto 40% by SE incharge of works for recorded reasons

Rough stone dry packing = Rough stone 11 m^3

Audit Approach:

The PWD schedule of rate stipulates rates for various size of bricks. The schedule of rate is being prepared after ensuring the availability and market rate. But the datas for brick were prepared adopting small size of brick. This would boost the cost of brick work as it involved use of mortar and number of brick more than that of higher size. In many cases work is entrusted on percentage tender. Consequently it would involve extra cost to the department. If the contractor use the available higher size of brick it would involve unintended benefit to the contractor.

6. CONVERSION TABLE

Length: Inches x 2.54 = cm Feet x 0.3048 =m Miles x 1.6093 = km Yard x 0.91440 = m	 Cm x 0.3937=Inches M x 3.2808 = Feet Km x 0.6214 = Mile M x 1.093613 = yard
AREA Sq.Inches x 6.456=cm^2 Sq feet x 0.0929 = m^2 Sq. yard x 0.83613 = sq m Acres x 0.40469 = Hectare Sq. Mile x 2.58999 = Sq.Km	 CM^2 x 0.155 = Sq.M M^2 x 10.7636 = sq.ft M^2 x 1.19588 = sq.yard Ha x 2.47105 = acres Sq. km x 0.3861 = Sq. mile
Volume Cubic metre = 1000 litres or 1 kilolitre Cubic inch x 16.39 = cm^3 Cubic feet x 0.0283 = m^3 Cubic yard x 0.76455 = m^3 Gallon x 4.54609 = litres Lpm = litre per minute	 Cm ^{3}x 0.061 = cubic inch M^3 x 35.287 = cubic feet M^3x 1.30795 = cubic yard Litre x 0.21997 = gallon Million cubic metre x 0.03531 = TMC
Weight Pounds x 0.4536 = kg Ton x 0.984 = Tonne (2240 lb) Tons x 0.000984= kg	 Kg x 2.205 =Pound Tonne x 1.0158 = Ton (1000 kg) Quintal = 100 kg 1 metric tonne= 1000 kg
GENERAL Lbs/sq.inch x 0.0703 = kg/cm^2 Newton/m^2x 1.00 = Pascal 1 Mpa x 10.2 = kg/cm^2 Neuton/mm^2 x 10.2 = kg/cm^2	Kg/cm^2x14.223 = lb/sq. in Pascals x 1 = Neuton/m^2 Kg/cm^2x0.098 = Mpa Kg/cm^2x 9.81 = Neuton/mm^2
DISCHARGE Cumec (cubic metre/second) = 35.345 cusecs (Cubic feet per second	Cusec = 375 gallon per minute

1 litre/second : 3051.2 cft/day 1 MGD :1.852 cusec flowing one day or 0.0524 cumec flowing one day 1 TMC : 17.123 MGD/annum	
Energy Power Horse Power = 746 watts or 0.746 kilo watt 1 KW = 1.34102 Horse power 1 KW/h =3.6 MJ 1J=0.737562 ft lbf 1 KJ = 0.27778 wh	
Velocity 1 fps = 0.0348 m/s = 1.0973 km/h 1 M/S = 3.2808 fPS = 2.2369 m/h 1 mile/h = 0.4470 m/s= 1.6093 km/h 1 KM/h = 0.9113 fPS = 0.6214 Mile/Hour	