A Novel Approach to Construct Flexible Pavements

Koudagani Venkatesh[1], Ajay Swarup[2], Umank Mishra[3]
[1]Research Scholar, [2]Professor, [3]Associate Professor
[1,2] Department of Civil Engineering, Sri Satya Sai University of Technology & Medical Sciences, Bhopal, Madhya Pradesh, India.
[3] Department of Civil Engineering, Shri Shankaracharya Technical Campus, Bhilai, Chhattisgarh, India.

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ABSTRACT *This paper aims at formulating a novel approach to design flexible pavements. The study of design data such as California Bearing Ratio (CBR) value, traffic data, drainage conditions, rainfall data, topography of the area etc. are considered. It is based on the design calculation by Indian road congress (IRC) codes.*
Construction aspects include usage of various materials, machines and manpower. Quality assurance (QA) and Quality control (QC) for various materials are incorporated in the construction procedure.
The construction of flexible pavement include several activities like excavation, embankment, sub-grade construction, granular sub base, wet mix macadam, prime coat, dense bituminous macadam and bituminous concrete.

Keywords: *California Bearing Ratio, Construction of Flexible Pavement.*

1. Introduction

Flexible pavements are those which have low or negligible flexural strength and are rather flexible in their structural action under application load. The flexible pavement layers may reflect non-recoverable as well as recoverable deformations of the layers including the sub grade on to the upper layers and also on the pavement surface. Thus if the lower layer of the pavement or soil sub grade gets deformed or undulated due to permanent deformation, the flexible pavement layers and also the pavement surface may get undulated in a similar pattern.

The vertical compressive stress is maximum on the pavement surface directly under the wheel load and it's equal to the contact pressure under the wheel. Due to the ability of flexible pavement layers to distribute the compressive stresses to a larger area in the shape of a truncated cone, the compressive stresses get decreased at the lower layers. Therefore by taking advantage of the stress distribution characteristics of the flexible pavement layers, the 'pavement layer system concept' was developed. According to this, the flexible pavement may be constructed consisting of a number of layers and the top layer has to be the strongest as the highest compressive stresses are to be sustained by this layer, in addition to the wear and tear due to the moving traffic and due to varying factors because of weather.

Lower layers of the pavement have to take up only lesser magnitudes of stresses and there is no direct wearing action due to traffic loads and is due to environmental factors. Therefore inferior materials with lower cost can be used in the lower layers. The lowest layer consists of selected soil which is compacted to the required thickness and density which is called the 'sub grade' and is laid on the prepared or compacted local soil or fill.

The flexible pavement structure is usually designed for a life of 15 years or more, but will need re-surfacing or strengthening layers to be laid periodically on the surface depending on the functional and structural deterioration caused due to the combined effect of traffic and weather.

2. Literature Review

For laying pavements studies for maps, reconnaissance and traffic which fall into the category of Engineering surveys have to be made.

2.1 Map Study

Topographic maps (from the Survey of India) are available with contour interval of 15 to 30 meters. Mostly rivers, hills, valleys are shown in the map. By studying these maps it can be inferred that several possible routes can be interconnected. Alignment should be avoided whenever valleys, ponds or lakes are encountered. Approximate location of bridge which the cross river should be maintained at short distance for economy, avoid bending of the river [1]. This study gives a rough guidance of the routes to be further surveyed in the field.

2.2 Reconnaissance

General characteristics of the area for deciding the feasible route were examined. Details collected during this survey are approximate values of gradient length and radius of curves of alternate alignment, Number and types of cross drainage structures, Soil types along the routes from the field identification test, Sources of construction material and water, Deciding the stable and unstable sides of the hill for alignment when it is passing through rows of hills and mountains areas.

Initially start with field inspection by walking or driving in a jeep. Details collected in this survey are: Details of route topography of the area, Length of road along alternatives, Geometrics: such as gradients that are feasible, curves and hair-pin bends, Terrain and soil conditions, Drainages characteristics of the area, Facilities/Resources, Road length passing through mountainous terrain, Recreation Potential, Strategic consideration, Economic Factors, Ecology [2].

The common review is from the Reconnaissance survey we get the details about route topography, length of road alternatives, gradients, soil type along the routes from the field identification test, Sources of construction material and water.

2.3 Traffic Survey

Traffic surveys conducted in the region form the basis for deciding the number of traffic lanes width, pavement design and economic analysis of highway project. Traffic volume counts of the classified vehicles are to be carried out on all the existing roads in the region, preferably for 24 hours per day for a week. Origin and destination surveys are very useful for deciding the alignment of the roads.

Traffic survey needed for Highway engineering are:

- Classified Traffic volume counts: The most common data needed for highway design is the volume of traffic. Volume/ flows are expressed in vehicles per hour or vehicles per day. It is customary to convert the mixed traffic into a Passenger Car Unit (PCU). Peak hour traffic is needed for the design of intersection to determine number of lanes in a carriageway.
- Traffic Growth Rate: Estimation of future traffic is important for geometric design, pavement design and economic analysis. The rate of growth is one of the most difficult elements to be determined.
- Axle Load surveys: axle load surveys are needed for designing pavements since commercial vehicles tend to be over loaded in India, and which cause much heavier damage than a standard axle of 8.2 tones.

It has been observed that surveys should include traffic volume count for 24 hours per day for a week. Traffic growth should be decided for 10 to 20 year periods. Traffic volume should be converted into PCU units. Details of axle load survey are considered to determine Vehicle damage factor.

2.4 CBR Method of Design

In order to design a pavement the CBR value of the soil sub grade is first evaluated. Then the approximate design curve is chosen by taking the anticipated traffic into consideration. Thus the total thickness of flexible pavement needed to cover the sub grade of the known CBR value is obtained. An estimation of the traffic is carried out keeping in view the existing traffic and the growth rate of traffic.

The soil strength is measured by CBR test. In which moisture content is selected and the procedure laid down. The thickness is given by 7 curves of IRC. The traffic is in terms of commercial vehicles per day which is the total number of vehicles in both directions.

Flexible pavements are those which are surfaced with bituminous (or asphalt) materials. These types of pavements are called flexible since the total pavement structure bends or deflect due to traffic loads. A flexible pavement structure is generally composed of several layers of materials which can accommodate this flexing. Flexible pavements comprise more than 90 percent of our paved roads.

There are different types of flexible pavements of which Hot Mix Asphalt (HMA) mix types are commonly used. Other flexible pavements use bituminous surface treatments (BST). HMA mix types differ from each other mainly in maximum aggregate size, aggregate gradation and asphalt binder content or type. In flexible pavements failure due to loads may result in bituminous surface fatigue, consolidation, settlement and shear developing in the sub grade or inadequate performance of the sub grade, road base and surface which are resulted due to inadequate pavement thickness [3].

2.5 Advantages of Flexible Pavements

- Flexible pavements are generally designed and constructed for a design life of 15 years. However if there is a constraint of funds, it is possible to decrease the initial cost of flexible pavement by resorting the design and construction in two stages. Thick bituminous layers form the costliest component of the flexible pavement structure. It is possible to initially provide a thin bituminous surface course and after a couple of years it is possible to lay thick bituminous binder and surface

course. The lower pavement layers may be designed for a longer design life and the initial bituminous layer may be designed for a lower design life.

- A standard design wheel load is made for flexible pavement design. The combined effect of wheel loads of different magnitudes, their repetitions and growth rate are taken into account in the design in terms of Cumulative Standard Axles (CSA).
- The functional evaluation studies can be carried out at desired intervals and the deteriorated functional condition of the road surface can be restored with a thin bituminous re- surfacing layer.
- Structural evaluation studies of the flexible pavement can be carried out periodically and the flexible pavement structure can be strengthened by laying an appropriately designed 'overlay. This in turn will result in reduction of compressive stresses and strains on all other existing pavement layers including the sub grade.
- It is possible to resort milling and recycling technique and thus utilise substantial portion of damaged bituminous pavement layers. This results in high salvage value of deteriorated flexible pavement material.
- The curing period for bituminous surface course is less and hence the surface can be opened to traffic within 24 hours [4].

2.6 Limitations of Flexible Pavements

- The bituminous pavements layers get deteriorated when exposed to stagnant water due to poor drainage of surface and subsurface water. Once stripping of bitumen start taking place, there is rapid deterioration by formation of potholes resulting in revelling of the bituminous surface.
- It is essential to carry out routine and periodic maintenance of the drainage system and the pavement surface.
- It is difficult or very expensive to carry out repairs of deteriorated bituminous pavements or patching of pot-holes under wet weather conditions.
- The total thickness of the flexible pavement and the quantity of hard aggregates required are higher than cement concrete (CC) pavements, particularly for the construction of highways passing though weak sub grade soil and carrying heavy traffic loads.
- For longer services, the life cycle cost of flexible pavements are higher than CC pavements when the initial cost, interest on capital and cost of maintenance, resurfacing and periodic strengthening are taken into account.
- Night visibility of bituminous surface (black top) is very poor, particularly under wet weather conditions.

3. Approach for Construction of Pavement

3.1 Design Factors Considered

CBR method recommended by IRC i.e. CBR value of the sub grade and the cumulative standard loads are considered. The Cumulative Standard Axles (CSA) value depend on the initial traffic, design period, growth rate, vehicle Damage Factor (VDF) values and lane distribution factor [7].

Calculations of CBR

Case I –Red Soil

Sample = Yellow soil (Clayey silt), Source of material =Quarry, Value of one Division of proving Ring = 2.5 Kg.

Table 1: Readings of CBR

Time of penetration c/0.25 mm/min	Penetration (mm)	Proving ring reading no. Divisions			Test load/corrected load 3xvalue of one division in (kg)			Standard load in(kg) on plunger area 19.64 cm	Unsoaked/soaked CBR% 4/5x100			Average CBR
1	2	3			4			5	6			7
		i	ii	iii	i	ii	iii		i	ii	iii	
0.0	0.0											
0.24	0.5	9	10	10								
0.48	1.0	16	15	15								

1.12	1.5	21	20	18								
1.26	2.0	25	24	23								
2.0	**2.5**	**26**	**24**	**23**	**66**	**68**	**67**	**1370**	**4.2**	**4.3**	**4.5**	**4.3%**
2.24	3.0	31	31	30								
3.12	4.0	34	34	34								
4.0	**5.0**	**32**	**33**	**37**	**90**	**97**	**92**	**2055**	**4.5**	**4.3**	**4.1**	**4.2%**
6.0	7.5	43	42	44								
8.0	10	46	45	47								
10.0	12.50	48	47	49								

Results

- Average CBR – 2.5 mm Penetration = 4.3%
- Average CBR – 5.00 mm Penetration = 4.2 %

Sample 1

2.5 mm Penetration

- CBR = Test load/ Standard load × 100% = (26×2.5/1370) × 100 =4.2 %

5 mm Penetration

- CBR = Test load/ Standard load × 100% = (32×2.5/2055) × 100 = 4.5%

Sample 2

2.5 mm Penetration

- CBR = Test load/ Standard load × 100% = (24×2.5/1370) × 100 = 4.3%

5 mm Penetration

- CBR = Test load/ Standard load × 100% = (33×2.5/2055) × 100 = 4.30%

Sample 3

2.5 mm Penetration CBR

- CBR = Test load/ Standard load × 100% = (23×2.5/1370) × 100 = 4.5%

5 mm Penetration

- CBR = Test load/ Standard load × 100% = (37×2.5/2055) × 100 = 4.1%

Average CBR at 2.5 mm Penetration = (Sample 1+ Sample 2+ Sample 3)/3 = 4.3%

3.2 Traffic Survey and Data Collection

Manual Method

A two lane road has been observed and has taken dimensions at Sehore. Also did the vehicular survey i.e. how many vehicles are passing from two sides for every hour counted with best accuracy and found out the peak hour, capacity and future serviceability. Traffic volumes are usually determined at different hours to ascertain peak hours. The traffic survey was conducted from 7 AM to 8 PM and the hourly traffic volume was obtained. The total entry traffic is the volume that enters in to the road from two sides at a particular time. These volumes are in terms of PCU/hr and Veh/hr. The PCU factor for each class of vehicle has been taken from IRC: 65-1976.

Dimensions of a Road

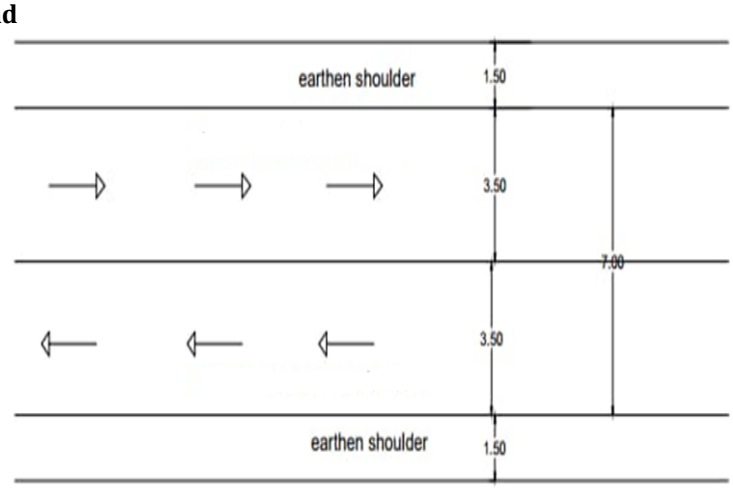

Figure 1: Dimensions of a Road

Traffic from Bhopal Road to Sehore Road

Table 2: Traffic Flow

Time Interval	2wheelers	3wheelers	4wheelers	6wheelers	Bicycles/ Rickshaw	Total vehicles/hr
8am-9am	15	2	4	3	2	26
9am-10am	8	3	3	2	2	18
10am-11am	9	3	2	2	3	19
11am-12pm	11	5		-	1	17
12pm-1pm	13	2	2	3	-	20
1pm-2pm	12	-	-	2	-	14
2pm-3pm	10	3	3	1	-	17
3pm-4pm	18	4	2	3	2	29
4pm-5pm	14	3	4	2	2	25
5pm-6pm	11	-	1	-	-	12
6pm-7pm	9	1	-	2	1	13
7pm-8pm	6	-	2	-	-	8
					Total vehicles per day from Bhopal Road-Sehore Road	**218**

Traffic from Sehore Road to Bhopal Road

Table 3: Traffic Flow

Time Interval	2wheelers	3wheelers	4wheelers	6wheelers	Bicycles/ Rickshaw	Total vehicles/hr
8am-9am	11	2	3	1	2	19
9am-10am	16	4	2	2	-	24
10am-11am	11	3	3	2	1	20
11am-12pm	17	2	4	2	2	27
12pm-1pm	7	1	2	1	2	13
1pm-2pm	9	3	-	3	2	17
2pm-3pm	10	-	2	-	1	13
3pm-4pm	14	2	2	2	3	23
4pm-5pm	11	1	3	1	-	16
5pm-6pm	10	-	-	-	2	12
6pm-7pm	3	-	2	-	-	5
7pm-8pm	5	1	2	1	-	9
					Total vehicles per day from Sehore Road - Bhopal	**198**

					Road	

Designing the pavement for construction of a road with the following data

1. Two lane carriage way
2. Initial traffic in the year of completion of construction = 416 CVPD (sum of measured traffic in both directions)
3. Traffic growth rate = 7.5 %
4. Design life = 15 years,
   - $A = P (1 + r)^n$ =416(1+0.075)^1 =447.2
5. Vehicle damage factor based on axle load survey = 2.5 standard axle per commercial vehicle
6. Design CBR of sub grade soil = 4%.

Result

1. Distribution factor = 0.75
2. N= $\frac{365\ X\ [(1+0.075)^{15}\ ]-1]}{0.075}$ X 447.2 X 0.075 X 2.5 =8000000 = 8.0 msa
3. Total pavement thickness for CBR 4% and traffic 7.4 msa from IRC:37 2012 chart1 = 680 mm
4. Pavement composition can be obtained by interpolation from Pavement Design Catalogue (IRC: 37 2012).
5. (a) Bituminous surfacing = 30 mm SDBC + 75 mm DBM
6. (b) Road-base = 250 mm WMM
7. (c) sub- base = 325mm granular material of CBR not less than 30 %

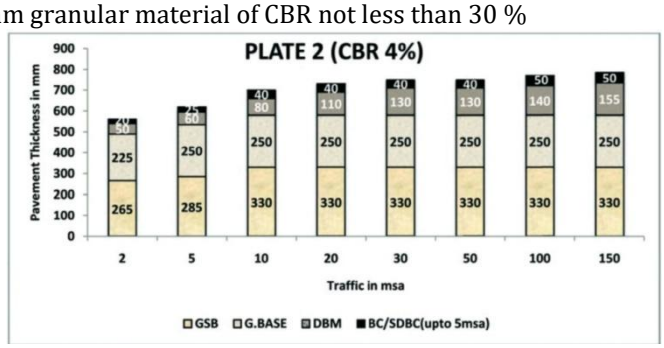

Figure 2: CBR design chart for determination of total pavement thickness for traffic with CSA of 1.0 to 150 msa [6].

4. Road Work

4.1 Granular Sub Base (G.S.B)

The materials of different required sizes and quantity from selected quarry, was sent to Research station office of the engineer-in-chief for design mix of Granular Sub Base (GSB). Mix is designed, and parameters like gradation, OMC %, and maximum dry density are mentioned in the copy of design.

GSB gradation III data is prepared as per Morth table 400-2 for 300mm compacted where in loose quality of aggregate are taken as

- 255.00 Cum – 9.5 mm to 4.75 mm – 66%
- 129.00 Cum – 2.36mm and below – 34%
- 384.00 = total quality of aggregate

Extra loose quantity of aggregate required = 384/ 300= 1.28 times the compacted quantity.

Hence a loose thickness of 260mm is provided at site after sufficient rolling at Optimum Moisture Content (OMC) and after attaining required compaction the compacted thickness will be 200 mm (the loose thickness is also 1.28 times the compacted thickness).

Table 4: Gradation of Granular Sub Grade (GSB)

IS Sieve	Weight Retained	% Retained	Cum% Retained	% Passing	Required as per specification
26.5mm	---------	----------	----------	100	100
9.5mm	11.3	38.27	38.27	61.73	65 – 95
6.3mm	5.39	18.25	56.52	43.48	50 – 80
4.75mm	1.83	6.19	62.71	37.29	40 – 65
2.36mm	2.37	8.02	70.73	29.27	20 – 35
Pan	8.63	29.23	99.96	0.04	08 – 22
Total	29.52				

4.2 Wet Mix Macadam (WMM)

The materials of different required sizes and quantity from selected quarry, was sent to Research station office of the engineer-in-chief for design mix of Wet Mix Macadam (WMM). Mix is designed, and parameters like gradation, OMC %, and maximum dry density are mentioned in the copy of design. On field the gradation of the WMM is compared with specified gradation and found out that it is in the specified limits. WMM gradation III data is prepared as per Morth table 400-2 for 225mm compacted where in loose quality of aggregate are taken as

- 89.10 Cum – 45 mm to 22.4 mm – 30%
- 118.8 Cum – 22.4mm to 2.36mm and below – 40%
- 89.10 Cum-- 2.36 mm to 75 micron -30%
- 297.0 Cum = Total loose quantity of aggregates

Extra loose quality of aggregate required = 297/ 225= 1.32Times are compacted quality. Hence a loose thickness of 330mm is provided at site offer sufficient rolling of OMC% and after attaining required compaction the compacted thickness will be 250 mm (the loose thickness is also 1.32 times the compacted thickness).

Gradation OF WMM

Table 5: Gradation of WMM

IS Sieve	Weight Retained	% Retained	Cum% Retained	% Passing	Required as per specification
53mm	---------	----------	----------	100	100
45mm	11.1	28.03	28.03	71.97	95 – 100
22.4mm	6.9	17.42	45.45	54.55	60 – 80
11.2mm	3.3	8.33	53.78	46.22	40 – 60
4.75mm	7.2	18.18	71.96	28.04	25 – 40
2.36mm	4.4	11.11	83.07	16.93	15 – 30
Pan	6.7	16.91	99.98	0.02	08 – 22
Total	39.60				

4.3 Bituminous Macadam (BM)

After obtaining mix design from R&B research station, Bhopal the bituminous macadam (BM) is laid as follows.

Tack coat over priming coat with bituminous emulsion of 0.20 kg/m2 is laid after the surface of the carriage way. The BM is mixed in hot mix plant as per the design and heated up to 150 to 1800c during mixing and the mix is dumped into the trippers and the same is conveyed in the site.

Everyday two samples are collected at a site or plant. The weight of sample mix is noted and the mix is immersed in the Benzene for one hour/required time then after the mix is kept in the bowl of extractor machine and a filter paper is placed over bowl after noting the initial weight of filter paper. The bituminous extractor is closed with top lid and it is revolved with given handle till total Benzene is mixed with bitumen which come out of the extractor machine.

The rotation of handle is stopped and left, the top lid is removed. Aggregate is kept over for one hour for evaporation of Benzene, the weight of aggregates is taken. The weight of bitumen in mix is equal to (weight of sample before test - aggregates weight +weight of on dust filter paper after test.

% of bituminous in mix = Wt of bitumen /Wt of mix x 100

The gradation of the mix is also done after obtaining the aggregates from extraction test and it is found that the gradation of the mix is within the specified limit The BM mix is transported by trippers to site and unloaded in the machinery. The loose thickness is set to 71mm and the uniform layer is laid continuously with paver.

The loose thickness is frequently measured with depth gauge and width of the road is also measured with tape. The BM is rolled with vibrator road roller when the mix is above 100 0C. The compacted thickness after rolling will be 50mm, the traffic is allowed on the surface after the mix is cooled.

Gradation of BM

Table 6: Gradation of BM

IS Sieve	Weight Retained	% Retained	Cum% Retained	% Passing	Required as per specification
26.5	--------	----------	----------	100	100

19.0	10.34	2.20	2.20	97.80	90 – 100
13.2	187.06	39.80	42.00	58.00	56 – 88
4.75	117.50	25.00	67.00	33.00	16 – 36
2.36	75.20	16.00	83.00	17.00	4 – 19
300mic	40.19	8.55	91.55	8.45	2 – 10
75mic	11.52	2.45	94.00	6.00	0 – 8
Pan	28.20	6.00	100.00	0.00	
Total	470.00				

Bituminous % Test for BM (Bitumen Extraction Test)

Time – 1.50 pm

- Paper weight – 10.30
- Next paper weight – 10.40
- Sample weight – 500.00 grams
- Next sample weight 483.10 + 0.10 = 470.00 grams
- 16.80/500.00 = 0.0336*100 = 3.36%

Time – 10.00 am

- Paper weight – 10.20
- Next paper weight – 10.40
- Sample weight – 500.00 grams
- Next sample weight 489.20 + 0.20 = 470.00 grams
- 16.60/500.00 = 0.0332*100 = 3.28%

4.4 Semi Dense Bituminous Concrete (SDBC)

As dealt with BM, gradation of SDBC is also dealt the same.

Gradation of SDBC

Table 7: Gradation of SDBC

IS Sieve	Weight Retained	% Retained	Cum% Retained	% Passing	Required as per specification
13.2	--------	----------	----------	100	100
9.5	10.42	2.20	2.20	97.80	90 – 100
4.75	188.45	39.80	42.00	58.00	35 – 61
2.36	118.38	25.00	67.00	33.00	24 – 39
1.18	42.62	9.00	76.00	24.00	15 – 30
300mic	33.15	7.00	83.00	17.00	9 – 19
75mic	52.09	11.00	94.00	6.00	3 – 8
Pan	28.41	6.00	100.00	0.00	
Total	473.50				

Bituminous% Test for SDBC

Time – 9.45 am

- Paper weight – 15.20
- Next paper weight – 15.60
- Sample weight – 500.00 grams
- Next sample weight 473.10 + 0.40 = 473.50 grams
- 26.50/500 = 0.053*100 = 5.30%

Time – 12.30 pm

- Paper weight – 15.30
- Next paper weight – 15.40
- Sample weight – 500.10 grams
- Next sample weight 469.90 + 0.10 = 470.00 grams
- 30.01/500.10 = 0.0601*100 = 6.01%

4.5 Levelling

Leveling is art of determining the relative heights of different points with respect to known/assumed TBM or BM.

For the leveling Auto leveling is used. First the tripod is spreaded apart and the instrument is fixed on the tripod tentatively levelled by shifting or rotating the legs of tripod and screws of instrument respectively. Setting the instrument bringing the bubble exactly at the centre of the circle makes the instrument stable. Care should be taken to not disturb the tripod while leveling.

Top levels of semi dense bituminous concrete (SDBC) of road in Sehore are taken. First the instrument station is selected such that from the bench mark (BM) is perfectly visible. The reduced level of BM is assumed as 100.00, then the staff is kept at the BM and the reading is taken. This is known as back sight (BS). Further readings are taken at 25.00m interval. These are known as intermediate stations (IS). The last point at which the reading on the staff is seen is known as Fore Sight (FS). After that the instrument is shifted to another point which is known as change point (CP). The instrument is shifted to another location without changing the position of staff. Again back sight, intermediate sights are taken and continued the levelling up to next change point and desired distances. The levels at every temporary bench mark are also taken. We should be careful while holding the staff so that shaking and bending of staff encourages the errors in staff reading.

With the help of levels taken, the thickness of SDBC is calculated by subtracting the top level of bituminous macadam (BM) from the top level of SDBC. It helps in checking the gradient of the road. The tampering of the road is also checked by the levels.

Longitudinal section (LS) helps in checking the gradient of the road. Cross section (CS) helps in checking the camber, estimates the level of all layers and computing quantities.

4.6 Preparation of Bituminous Mix at Hot Mixing Plant

The major components of the Bitumen Mixing Plant are:

Bins - 4 numbers

There are four types of bins to store four different sizes of aggregates at the batching plant.

Figure 3: Bins

- **Cold conveyer belt**:
  This belt is used to transfer the aggregates from bins to dryer
- **Fuel tank:**
  This tank is used to store the fuel, which is flammable. Different types of fuels used in this tank like kerosene, petrol, diesel etc are used.
- **Bitumen tanks:**
  This tank is used to store the bitumen which is of different grade for different uses
- **Dryer cum drum mixer:**
  This mixer is used to mix different sizes of aggregates, bitumen which enter from cold conveyor belt.
- **Hot conveyer belt:**
  This belt is used to transfer the bituminous mix which is well mixed from dryer cum drum mixer to the hopper.
- **Hopper:**
  This component is used to collect the bituminous mix from hot conveyor belt and this will load the bituminous mix into the truck.

Figure 4: Bituminous Hot Mixing Plant

4.7 Mixing Procedure for SDBC

Four Bins are named as 1, 2, 3 and 4 end are used to store the aggregates of different sizes. The sizes of aggregates and their proportions are taken as

Bin - 1: This bin consist of aggregates size 13.2mm to 10mm. These are used at a proportion of 30% of the total aggregates.

Bin - 2: consist of aggregates size 10 to 5mm which are used at a proportion of 25% of 100%

Bin - 3: consist of aggregates size < 5mm

Bin - 4: consist of Filler material with 2% dust.

These aggregates are gathered and carried from the bins to the cold conveyer belt. This cold conveyer belt transfers the aggregates and it is connected to the dryer cum drum mixer. From another side, bitumen and fuel tank is connected to the dryer cum drum mixer through two different pumps. From one of the pumps, fuel is pumped in to produce flame. After producing flame, bitumen from other pump will reach the drum mixer.

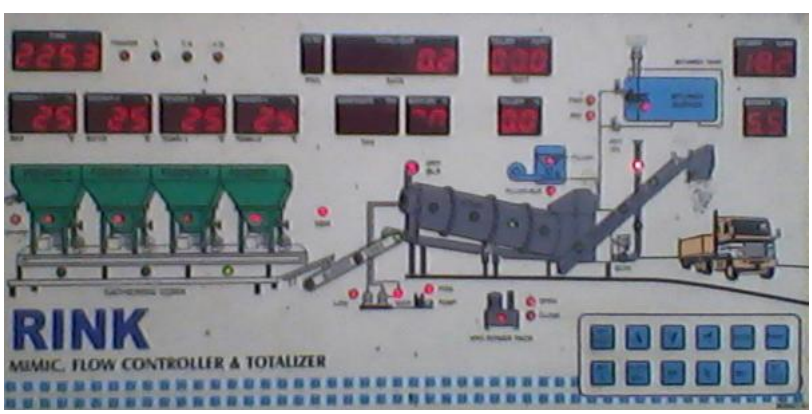

Figure 5: Bituminous Hot Mixing Plant Flow diagram

Dryer is located in a place where these aggregates and bitumen are mixed under hot conditions. Dryer is connected to wheel through which it can rotate rapidly. For this dryer, a hot flame is produced manually which (temperature) is maintained generally at 120o – 140o C. Under this temperature, the aggregates and Bitumen will mix properly. The temperature in the drum should not exceed 180oC. If it exceeds the maximum limit, the drum mixture may get burnt. Well hot mixed bitumen mixture is transferred from the dryer to hopper through hot conveyer belt. From this hopper the mix is collected in the truck (vehicle) and transported for the construction (laying) of the pavements.

There is a control room which is operated manually. This controls all required proportions of aggregates, filler (dust) and bitumen materials. The required proportions are set in the control room and according to the pre set setting, desired proportions of materials are sent in to the chamber.

5. Machinery and Materials Used for the Construction of Roads

5.1 Machinery and Components

Mechanical Paver or (Finisher)

This is one of the most important equipment in the construction of roads since it is used to spread the bituminous mix at required length and for required depth. In order to operate this equipment skilled person will required.

Figure 6: Mechanical Hot Mix Sensor Paver

The finisher is designed to produce a uniform level riding surface and to correct small irregularities automatically on the pavement surface. It consists of receiving hopper at the back to receive the bituminous mix. Two wheels exists on the equipment which play a major in the laying of road to spread the bituminous mix and to provide camber.

Rollers

Rollers are used for the compaction of road surface. There are mainly two types of rollers which are mainly used in the construction and laying of road surface.

Static roller

Figure 7: Static Roller (8 to 10 tonne)

This equipment is mainly used for the compaction of granular sub-base such as gravel, crushed stone, sand macadam and bituminous concrete etc.

Vibratory roller

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Figure 8: Vibratory Roller

This is also used for compaction of bituminous road surfaces. Vibratory road roller which weighs 45Tonnes has been used in the laying sight. The advantage of vibratory road roller over static road roller is that extra (required) compaction can be obtained with vibratory road roller. On application of vibrations with this roller, voids will be completely removed.

Shovel

Shovels are mainly used to spread or lay the bituminous mix manually if uniform thickness is obtained with mechanical paver. A shovel is a tool for digging, lifting, and moving bulk materials such as soil, coal, gravel, snow, sand or ore.

Most shovels are hand tools which consist of a broad blade fixed to a medium-length handle. Shovel blades are usually made of sheet steel or hard plastics and are very strong. Shovel handles are usually made of wood (especially specific varieties such as ash or maple) or glass-reinforced plastic (fiberglass).

Hand shovel blades are made of sheet steel usually which is folded at the back to make a socket for the handle.

Figure 9: Shovel

Depth Gauge

Depth gauge is an instrument which is used to check the thickness or depth of the bituminous layer at various locations in order to get uniform thickness of the road.

Figure 10: Depth Gauge

Tipper

This is used to transport the bituminous mix from the hot mix plant to the site of construction (laying) of road.

Figure 11: Tipper

6. Different Type of Materials Used

6.1 Bitumen

Bitumen is a visco-elastic, hydro carbon material and it is obtained artificially by fractional distillation of crude petroleum, or it is obtained naturally by means of lake asphalt. Bitumen mainly consist 95% of carbon and hydrogen and up to 5% of sulphur. Nowadays, the words bitumen and asphalt are being used like synonyms but there is some difference between these two. If bitumen consist any inert gases that bitumen is called “asphalt”. Bituminous materials are very commonly used in highway construction because of their binding nature and water proofing properties.

There are different types of bitumen grades for different uses for different locations. The grades of bitumen used for pavement construction work of roads and airfields are called paving grades and those used for water proofing of structures and industrial floors etc. are called industrial grades.

The bitumen grade is specified in terms of penetration value since the penetration test is for determination of the hardness or softness of bitumen by measuring the depth in tenths of a millimeter to which a standard loaded needle will penetrate vertically in five seconds.

There are mainly three grades of bitumen used they are

- 30/40
- 60/70
- 80/100

30/40 or 30-40 grade bitumen means that the penetration value of the bitumen is in the range of 30 to 40 at standard test conditions.

30/40 grade bitumen is mainly used in hot climate conditions and in very important structures such as runways.

80/100 grade is mainly used in cold climate conditions and in normal conditions 60/70 used. In India 60/70 and 80/100 grade bitumen are used for construction (laying) of roads.

6.2 Bituminous Emulsion

Bituminous emulsion is a stabilized suspension of bitumen in water or simply it is one of the liquid forms of the bitumen. Bituminous emulsion is used largely in road surfacing applications. Bituminous emulsion is sprayed on the road when constructing new roads or road renewal work. It is used as prime coat and tack coat.

If bituminous emulsion is applied/sprayed on the WMM (Wet Mix Macadam) this is called "Prime coat". If bituminous emulsion is applied/sprayed on the bituminous surface which is called "tack coat". When the emulsion is applied on the road, it breaks down and the binder starts binding the aggregates though full binding power develops slowly when the water evaporates. Emulsions are mainly used in the bituminous road constructions, especially in maintenance and patch repair works. The main advantage of emulsion is that it can be used in wet weather even when it is raining. Emulsions also have been used in soil stabilization, particularly for the stabilization of sands in deserts areas.

6.3 Aggregates

Different types and sizes of aggregates are used for preparation of different type layers of road.

Table 8: Sieve Analysis

S.No	Sieve designation (mm)	Percentage of passing through sieve
1	26.50	100
2	4.75	25-45
3	0.75	<10

Aggregates used for preparation of WMM (as per Job Mix)

- 45 mm to 22.4 mm size of aggregates – 30%
- 22.4mm to 2.36mm and below size of aggregates – 40%
- 2.36 mm to 75 micron size of aggregates (filler or dust) – 30%

Aggregates used for preparation of BM (as per Job Mix)

- 20 mm size of aggregates - 30%
- 12 mm size of aggregates – 60%
- 6 mm size of aggregates – 10%

Aggregates used for preparation of SDBC (as per Job Mix)

- 12 mm size of aggregates - 40%
- 6 mm size of aggregates – 50%
- Dust /Filler material – 10%

7. Formation of New Roads

7.1 Steps in Construction of New Bituminous Road in Rural Areas

- Preparation of existing surface
- Preparation of Granular Sub Base (GSB)
- Preparation of Wet Mix Macadam (WMM)
- Preparation of Bituminous Macadam (BM)

- Preparation of Semi Dense Bituminous Macadam (SDBC)
- Formation of earthen Shoulders
- Finishing and opening to traffic

7.2 Preparation of Existing Surface

Existing surface should be made free from ruts and undulations. Earthwork excavation is done by machinery called JCB (Josephy Cyril Bamford). This is one type of excavator used to cut the trenches (if any) by removing the soil including rock from its original position.

Figure 12: JCB

7.3 Preparation of GSB

This is the first layer in the construction of road. According to MORT&H table – 200 the materials of required sizes in required quantity are selected for construction of new road. Granular material shall be crushed rock, crushed slag or crushed concrete. The material shall be well graded and be within the grading limit. In this layer the gravels of required size are spread along the road and water is applied to that. After application of water, compaction should be done with any roller (static or vibratory), but for earthen roads mainly static rollers are preferred. Compaction and providing of water to the road is done for two days.

7.4 Preparation of Wet Mix Macadam (WMM)

Figure 13: WMM before compaction

Figure 14: WMM after compaction

This is the second layer of the road which consists of metal (fine aggregates and coarse aggregate) and rock filler material (rock powder or dust). WMM is a new technology .This layer is laid at a thickness of 250mm (loose mix) upon compaction with roller (vibratory or static), this layer becomes 200mm thick.

7.5 Application of Binder (Prime Coat)

On the prepared Wet Mix Macadam, a thin layer is sprayed manually by using sprayers or buckets. This Prime coat is one of the bituminous emulsions and it is used to "protect the integrity of the granular base during construction and help to reduce dust. In the case of a base which is to be covered with a thin hot mix layer or a chip seal for a low volume roadway, priming ensures a good bond between the seal and the underlying surface which otherwise would have a tendency to delaminate.

7.6 Preparation of Bituminous Macadam (BM)

Immediately after application of prime coat, bituminous macadam is laid on the road since prime coat is used as binder it will provide the bond between two surface layers i.e., WMM and BM. Bituminous Macadam or Bituminous bond macadam is a premixed construction method which consists of one or more compacted crushed aggregates premixed with bituminous binder. The prepared mix is transported by truck to site and it will pour mix into the mechanical paver. This paver will spread the bituminous mix at required depth and length.

Figure 15: BM before compaction

Figure 16: BM After compaction

In our site the BM is laid which consist a loose thickness of 68 to 73m. Upon compaction with vibratory roller this layer will reduce to 45mm.The bitumen grade used in this BM is 60/70.

7.7 Providing Camber and its necessity

From this layer onwards one should take care about providing of "CAMBER" (1 in 50). Camber is the cross slope provided on the road in order to avoid the infiltration of water into the road. The life span of road mainly depends on how well we provide the camber since if water enters into the road surface, the soil which is present below the road surface becomes softer which inturn reduce the strength of soil. This results in sinking of road and occurrence of undulations.

The BM is essentially a base/binder course and hence it should be covered by a suitable surfacing courses before it expose to traffic. BM is considered to be much superior to any other type of base course materials such as WMM with respect to load dispersion (carrying) characteristics and durability.

7.8 Application of Binder (Tack Coat)

Once the preparation of BM is completed, one needs to apply the binder to the prepared surfaces as per requirements. Tack coat (also known as bond coat) is a light application of asphalt or bituminous emulsion between hot mix asphalt layers designed to create a strong adhesive bond without slippage. Heavier applications may be used under porous layers or around patches where it also functions as a seal coat.

Without tack coat the bituminous layers in a road way may separate and which reduces the structural integrity of the road and may also allow water to penetrate the structure.

There are some differences between prime and tack coat. Prime coat will protect the integrity of GSB during construction and reduces the dust because it is used on the W.M.M. layer. Tack coat mainly helps to increase bonding strength between BM. and S.D.B.C. Without tack coat, the bitumen layers may separate which leads to the reduction of the strength of the road.

7.9 Preparation of Semi-Dense Bituminous Concrete (SDBC)

The preparation of BM and SDBC are same but the grade of bitumen and type of aggregates used in this SDBC are different. The grade of bitumen used in this preparation of SDBC is 80/100 because it is the final layer on the road surface for it to be smooth and without any unevenness. The size of aggregates used in the preparation of SDBC is mainly 6mm, 12mm.

After SDBC is spread, the road has to be rolled with vibratory roller to make road smooth and to remove voids (empty spaces) in the road.

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Figure 17: SDBC after compaction

7.10 Finishing and Opening to Traffic

The prepared road is opened to traffic after 24 hours. After completing the preparation of the road should be checked by Quality Control authority. The setting time of bituminous road mainly depends on weathering conditions.

8. CONCLUSION

Load distribution is an important factor considered for the design of pavements in transportation system. Even though flexible pavements have less life span compared to rigid pavements, the following advantages make flexible pavements widely used across the world.

- Load distribution will be in a form of a grain to grain transfer hence easy to access any layer in repairs which inturn reduce maintenance cost.

- Provides good accessibility and causes less danger to Human life.
- Can be made to any speed limit.
- The aggregates which are used in construction of flexible pavements can be tested for attrition, abrasion, crushing, impact and shape which provide wear and tear, high strength and accessibility.
- Flexible pavements can be put into service much earlier compare to rigid pavements.
- Using hot mix, all aggregates can be closely binded.
- Usage of emulsions provides more accessibility.
- Considering CBR value for the pavements made to increase stability.

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