New Technology Initiatives in Rural Roads and Use of Marginal Materials

Roller compacted concrete pavements and Interlocking concrete block pavements

National Rural Infrastructure Development Agency

Ministry of Rural Development

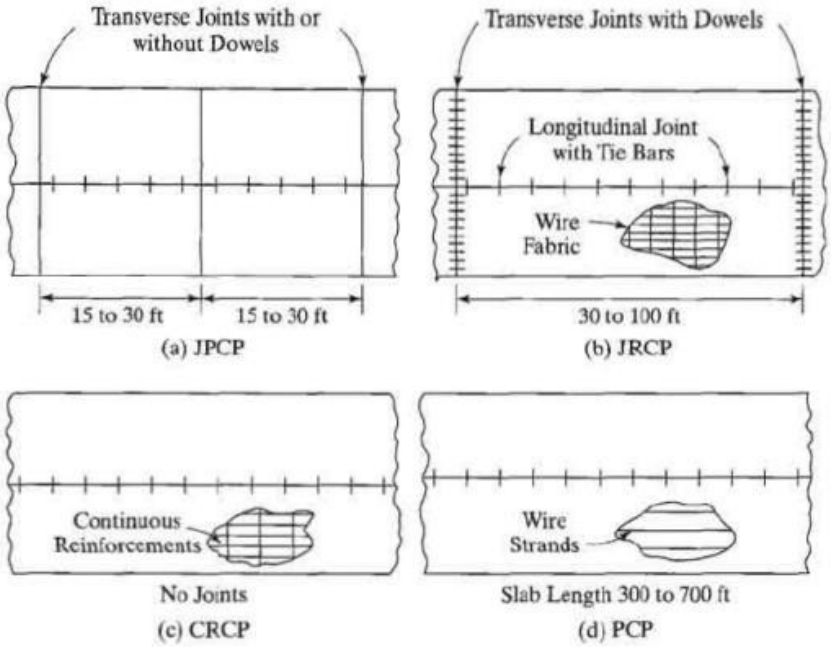
National Institute of Technology

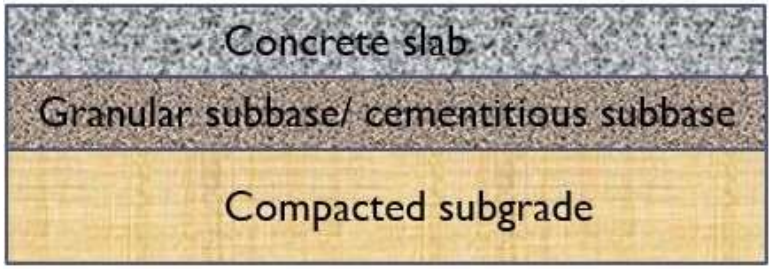
Warangal, Hyderabad

Lecture 2

Roller compacted concrete pavements and Interlocking concrete block pavements

Concrete Pavement types

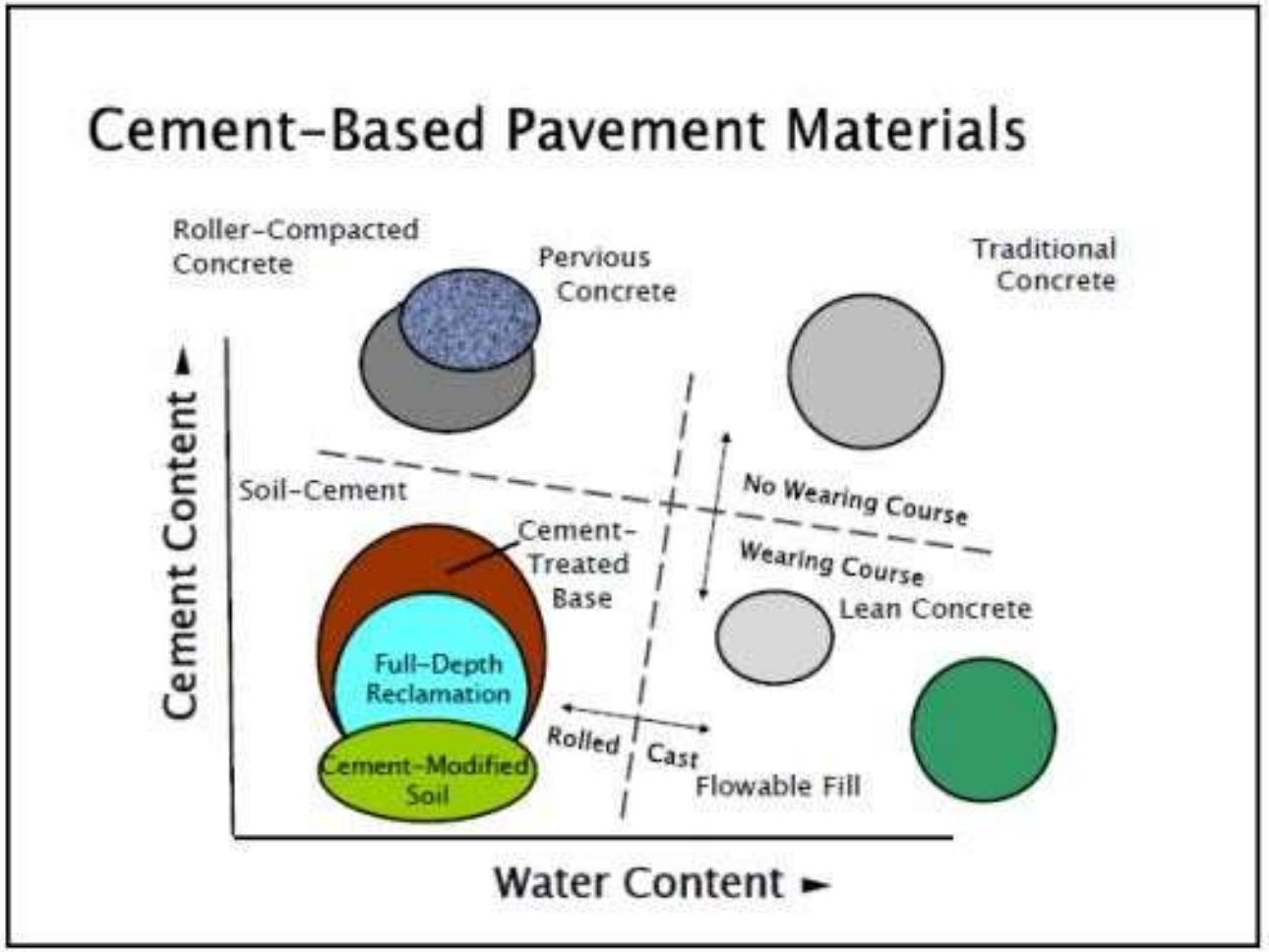




Types of concrete pavement (Huang, 2008)

Roller compacted concrete pavement

- RCCP as per MORD specification (34) for low volume roads
- Successfully used in West Bengal, Madhya Pradesh in low volume roads
- RCCP gets its name as heavy vibratory steel drum and static rollers are used to compact it into final form


Cement-Based Pavement Materials
Roller-Compacted Concrete
Pervious Concrete
Traditional Concrete
Cement Content
Soil-Cement
No Wearing Course
Wearing Course
Cement-Treated Base
Lean Concrete
Full-Depth Reclamation
Rolled
Cast
Cement-Modified Soil
Flowable Fill
Water Content

Roller compacted concrete gets its name from heavy vibratory steel drum rubber tire rollers used to compact it into final form

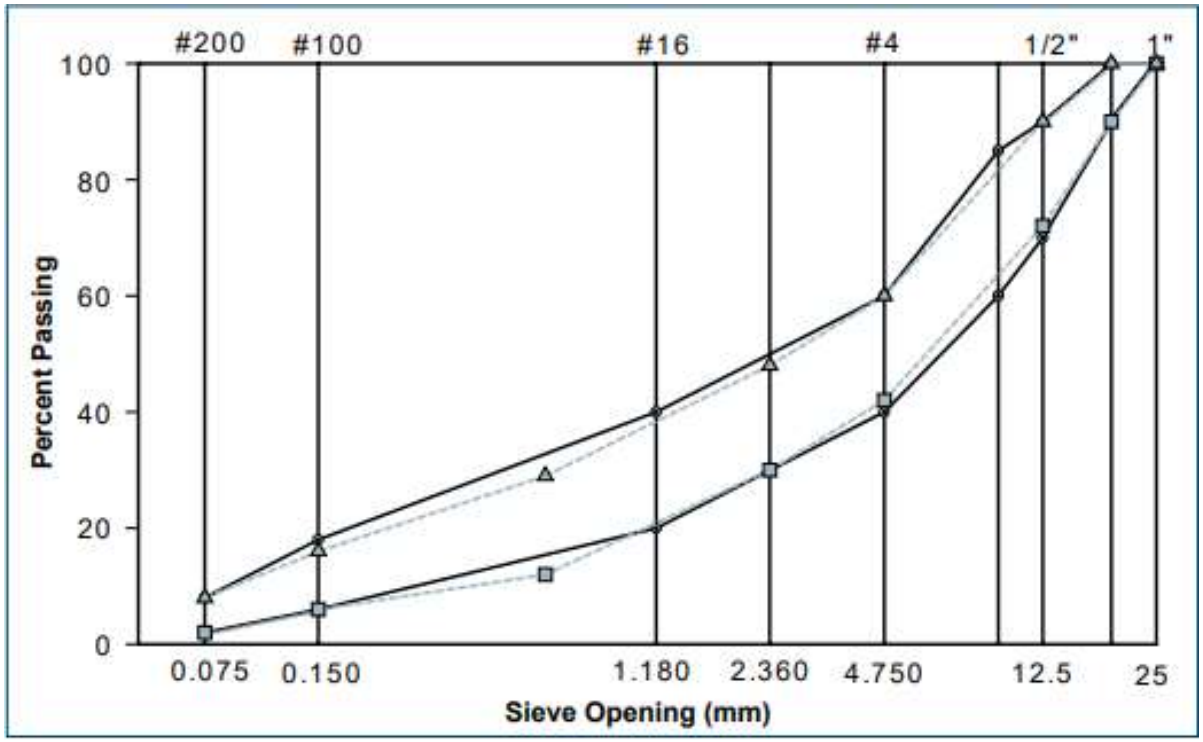
RCC has similar strength properties and has the same basic ingredients as conventional concrete – but has different composition

RCC combines various aspects of conventional concrete materials with construction practice of asphalt pavements

Salient features of Roller compacted concrete pavement

- RCC has similar strength properties and consists of the same basic ingredients as that of conventional concrete – well graded aggregates, cementitious materials, and water – but has different mixture proportions
- RCC has high percentage of fine aggregates, which allows for tight packing and consolidation
- RCC mixtures should be dry enough to support the weight of roller after placement, yet wet enough to ensure an even distribution of paste
- RCC can be placed using conventional asphalt paver, with a standard or high density paver screed, followed by a combination of rollers for compaction

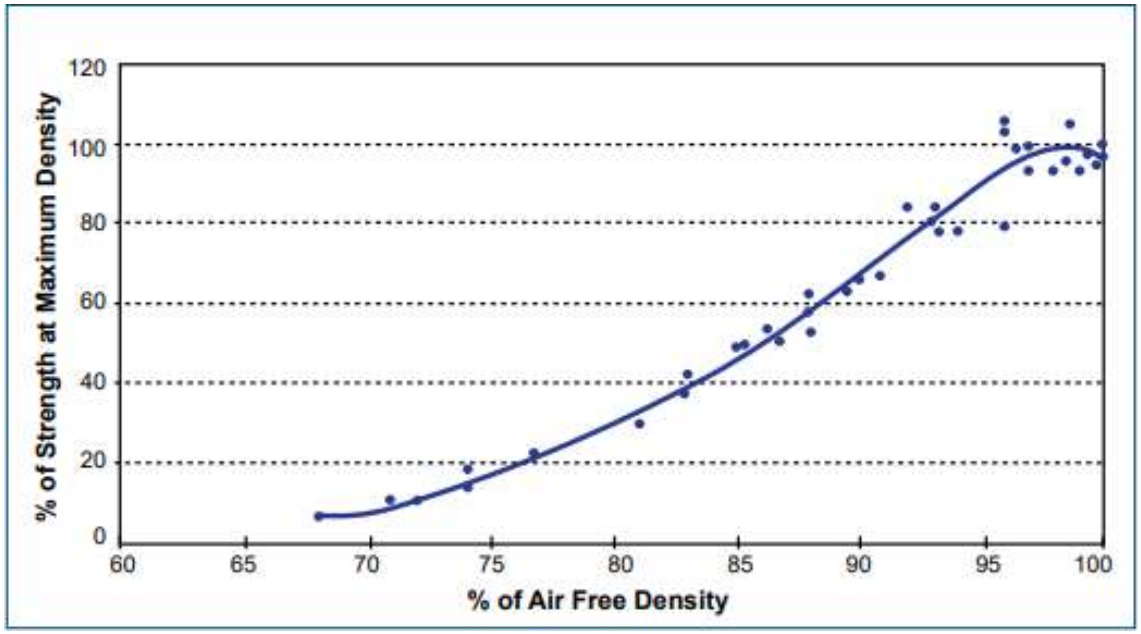
Aggregate gradation of RCC



Aggregate gradation of RCC mix (solid black line) and intermediate asphalt layer gradation (blue dotted line)

Roller compacted concrete - salient features

- RCC mixtures should be dry enough to support the weight of the rollers after placement, at the same time wet enough to ensure uniform distribution of paste
- Coating of aggregate particles must be achieved in-order to obtain strong and durable pavements
- Achieving the required density is the key for the enhanced load bearing property of RCC pavements
- Rolling must occur before cement hydration harden the paste between the aggregate particles



Schrader, 1992

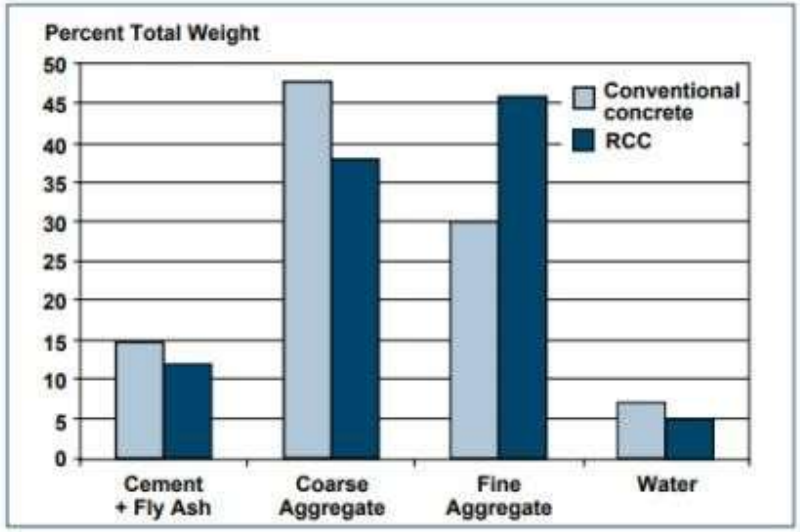
Comparison of Conventional CC with RCC pavements

General Materials and Practices	Conventional Concrete Pavements	RCC Pavements
Mix material Proportions	Well graded coarse and fine aggregate constitutes 60 – 75% by volume; w/c 0.4 – 0.45	Dense and well graded aggregates constitutes nearly 75-85% of RCC mixture by volume; w/c ratio 0.35 – 0.4
Workability	Mixture is plastic and flowable, slump is about 2 inches	Mixture is damp, dense graded aggregates. Zero slump concrete
Paving	Slipform pavers	Placed using heavy-duty, self propelled asphalt paving machine, Forms are not required
Hydration	Proper hydration of the mixture is necessary for long term durability	
Curing	Thorough curing is required	
Cracking and load transfer	Location of cracks are controlled by cutting joints	Joints are not usually sawed. However sawing prevents the occurrence of random cracks

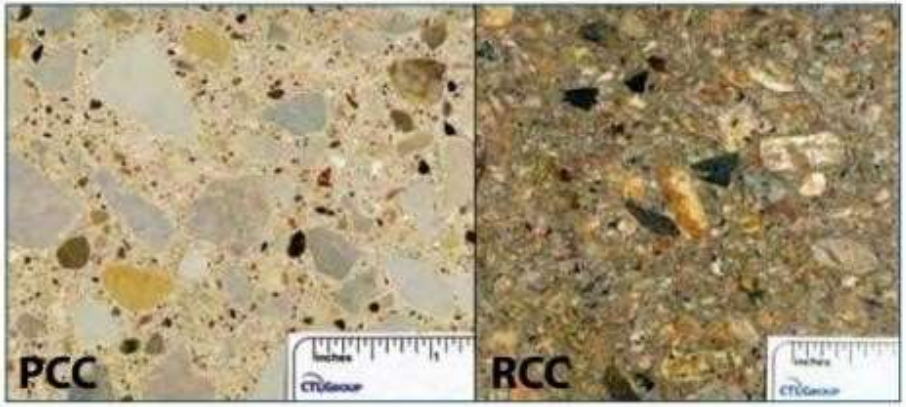
Features of Roller compacted concrete pavements

Features	Advantages
Low paste content	Less concrete shrinkage
Low permeability	Enhances durability and resistance to chemical attack
High flexural strength	Supports heavy, repetitive loads without failure, which reduces maintenance costs and down time
High compressive strength	Withstands high concentrated loads and heavy industrial and military applications
High shear strength	Reduces rutting and subsequent repairs
Aggregate interlock	Provides high shear resistance at joints to prevent vertical displacement or faulting
No steel reinforcement or dowels No forms or finishing	Speeds and simplifies construction, reduces cost and minimises labour
No formed or sawn joints	Speeds construction and reduces cost
Light coloured surface	Lighting requirements are reduced for parking and storage areas

Comparison of Conventional CC with RCC pavements

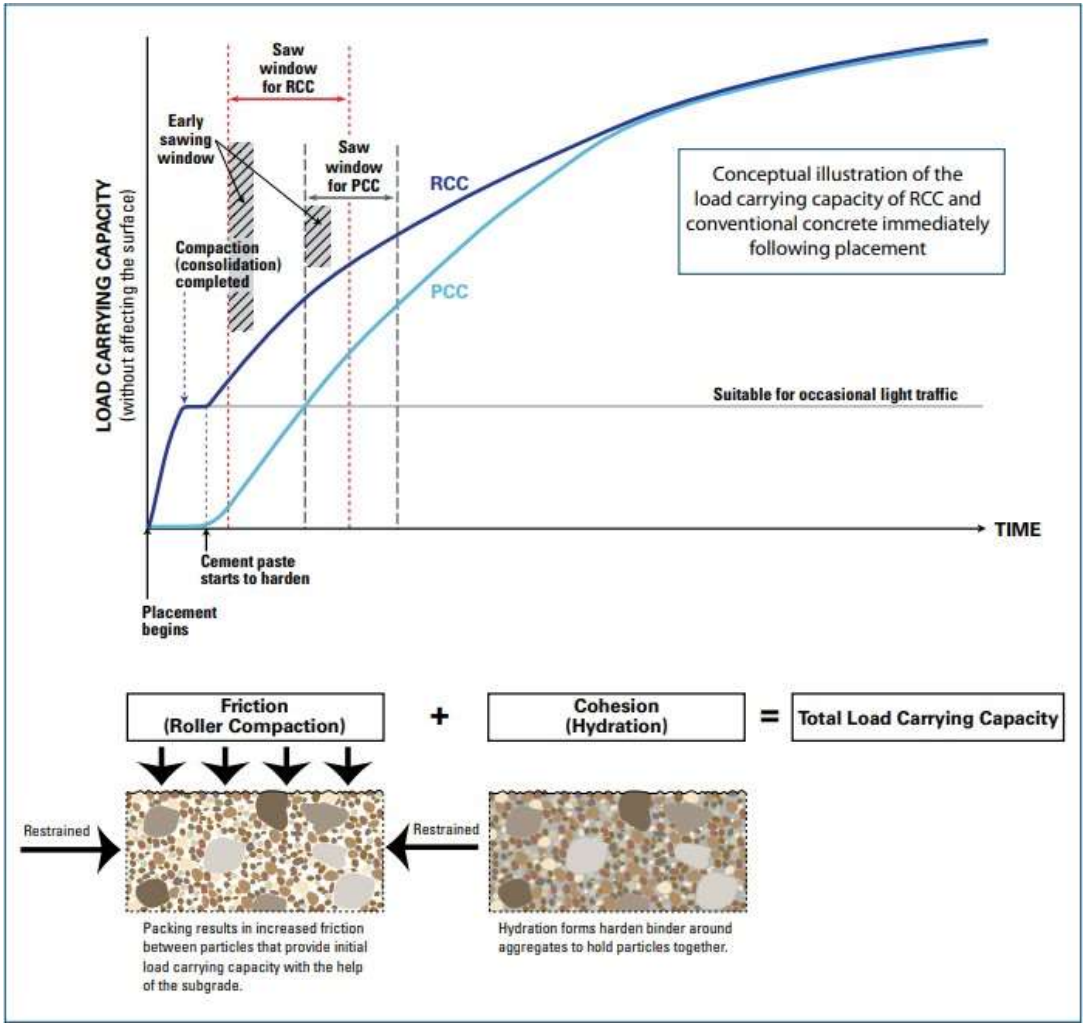


Typical material comparison in PCC and RCC mix



Comparison of aggregate distribution in conventional PCC and RCC mix

Salient features of Roller compacted concrete pavement



- Conventional concrete, immediately after placing is in plastic stage until hydration begins to harden the paste and bind the particles together
- Until the sawing window is reached or passed, conventional concrete does not have enough strength to support occasional light vehicle traffic
- In contrast RCC has enough load carrying capacity because of angle of internal friction mobilized by aggregate interlocking
- However traffic in both RCC and PCC is not recommendable until it reaches an adequate compressive strength (13.8 to 17.2 MPa

RCCP Mix design

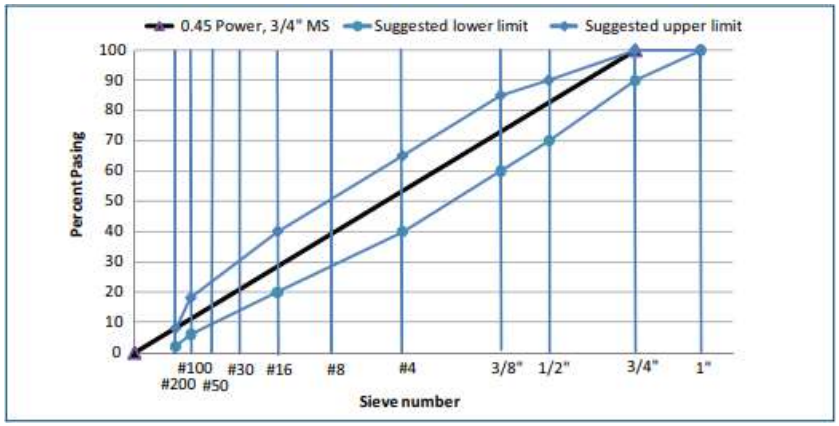
- Roller compacted concrete is a zero-slump concrete
- The mix shall be proportioned by weight of all ingredients such that the desired target strength is achieved
- The mix design shall be based on flexural strength of concrete
- The moisture content is selected so that mix is dry enough to support the weight of a vibratory roller, and yet wet enough to permit adequate distribution of paste throughout the mass during mixing, laying and compaction operations

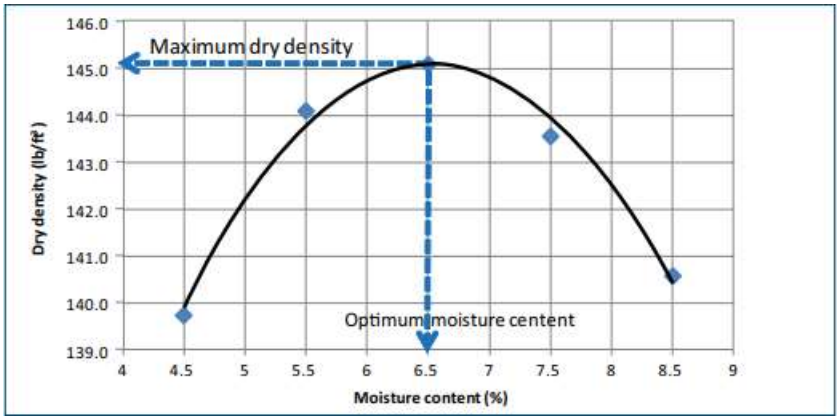
RCCP mix design

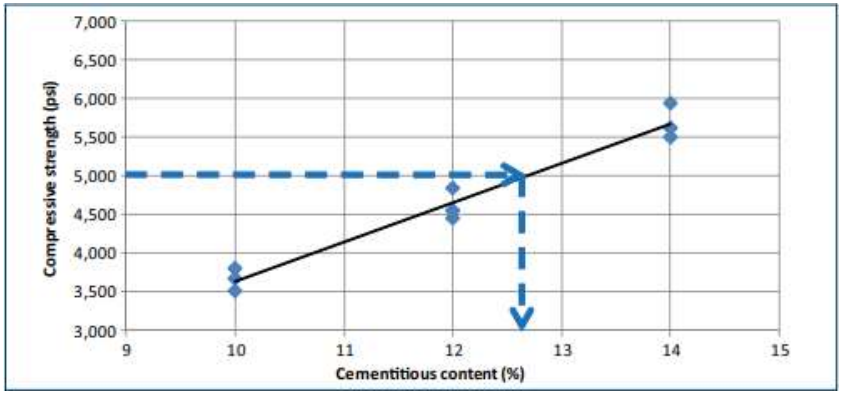
Procedure

- Choose well graded aggregate gradation. Determine blending proportions
- Select a mid range cementitious content
- Develop moisture – density relationship plots
- Test specimens and select the required cementitious content
- Calculate mixture proportions

RCCP mix design







- The water content may be in the range of 4-7% by weight of dry material including cement
- Trial mixes may be made with water contents in the range of 4 – 7%, at increments of 1%
- The optimum moisture content which gives the maximum density shall be established
- The exact moisture content requirement in the mix shall be established after making field trial construction

RCCP mix design

- Using the moisture content so established, a set of six beams and cubes shall be prepared for testing on 7^{th} and 28^{th} day
- If the flexural strength is lower than the desired strength, the trials should be repeated after increasing the cement/fly ash content until the desired strength is achieved

RCCP – Pavement design

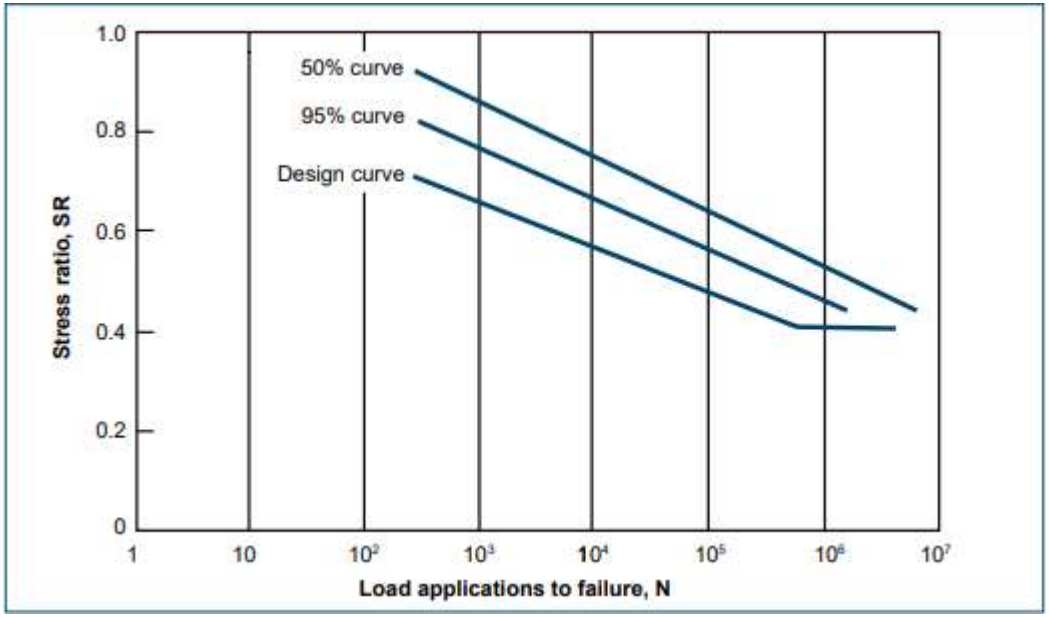
- Similar to that of Jointed Pavement (IRC SP 62-2014)
- Suitable crack spacing/joint spacing to be assumed

4.9 Roller Compacted Pavement

Roller Compacted Concrete Pavement (RCCP) as per MORD specifications (34) can also be used for the construction of pavements for low volume roads. RCCP is very popular for low volume roads in developed countries. In such pavements, the cracks may develop on its own to form joints. It has been successfully used in West Bengal also under PMGSY programme. Assuming a thickness of RCCP as 200 mm, the spacing of the cracks to be 6 m, an initial of traffic of 100 CVPD, a k value of 100 MPa/m , Zone I, 90 day modulus of rupture = 4.22 MPa, the total of wheel load and curling stress from excel sheet for a 200 mm slab = 3.60 MPa < 4.22 MPa. The thickness of 200 mm is appropriate.

RCCP Pavement design

- The Portland Cement Concrete Association method considers the flexural stresses and fatigue damage and wheel loads within the allowable limits



PCA Fatigue relationship for RCC (1987)

RCCP Compaction

- Compaction by Double drum smooth-wheeled vibratory rollers of minimum 80 – 100 kN static weight
- The number of roller passes shall be determined during trial construction by measuring the in-situ density and the scale of the work to be undertaken

  - There shall be preliminary pass (without vibration) to bed the lean concrete and again a final pass (without vibration) to remove the roller marks
  - Target compaction density to be achieved is 97%

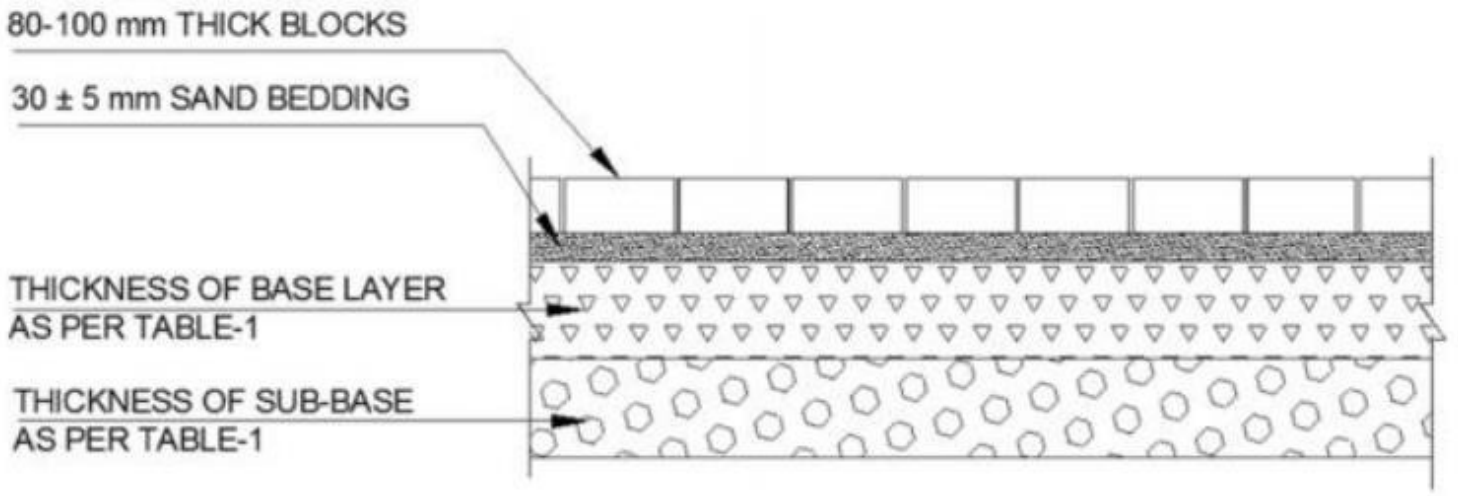
RCCP Construction pics from MP

RCCP rural road in WB

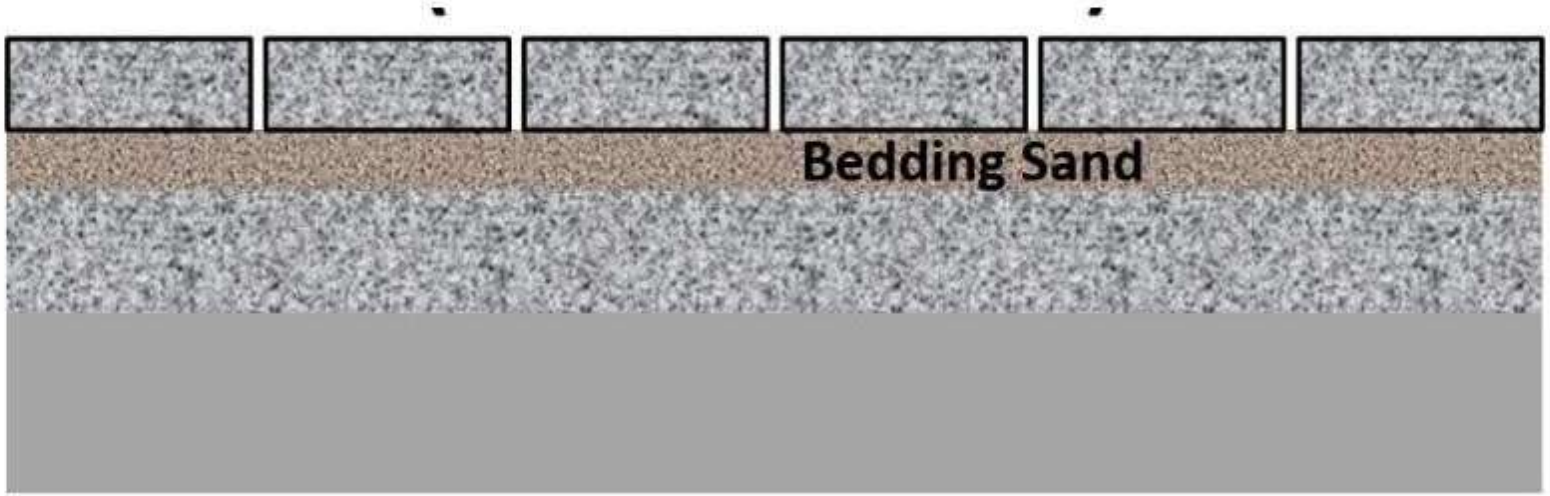
Limitations of Roller compacted concrete pavement

- RCC smoothness is not adequate for high speed pavement application
- Multiple lifts must be placed within an hour to ensure good and monolithic pavements
- Compaction requirement requires 96% dry density to be achieved towards the edge and 98% dry density towards the interior
- RCC in hot weather require more attention to reduce the evaporation loss and water loss

Interlocking Concrete Block pavement (ICBP)



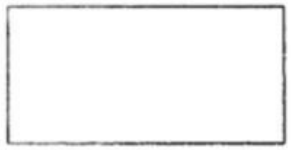
IRC SP 63 - 2014



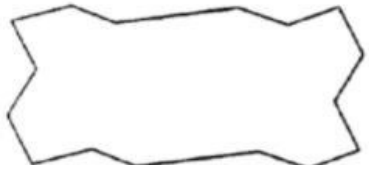
Typical Block Pavement Section

Block Thickness: (a) Light Traffic – 60 mm (b) medium traffic (less than 10 msa) 60 – 80 mm (c) heavy traffic (10-20 msa) 100-120 mm

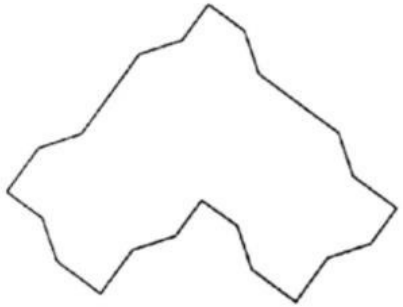
Suitable foundation, joint gap, gradation of bedding sand and jont filling sand are crucial



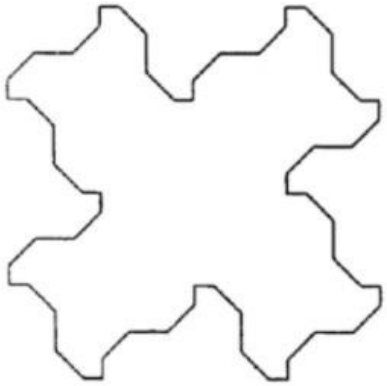
(i) INITIAL SHAPE AND SIZE SIMILAR TO PAVING BRICK



(ii) DENTATED TO PROVIDE KEY WITH ADJOINING UNITS, RETAINING ESSENTIALLY BRICK DIMENSIONS

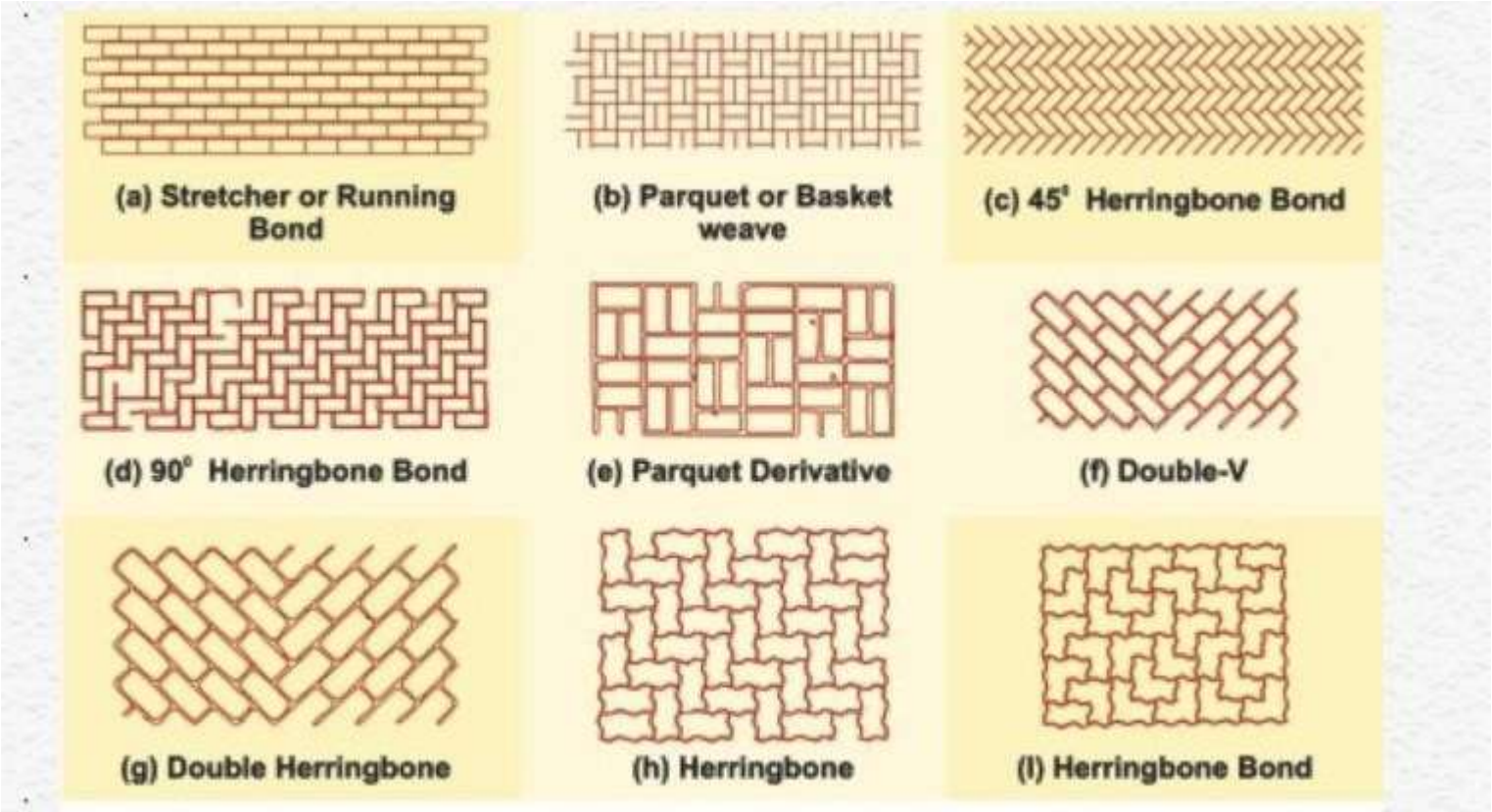


(iii) NEW SHAPE FOR BETTER PERFORMANCE UNDER TRAFFIC AND PERMITTING MECHANICAL LAYING OF BLOCKS

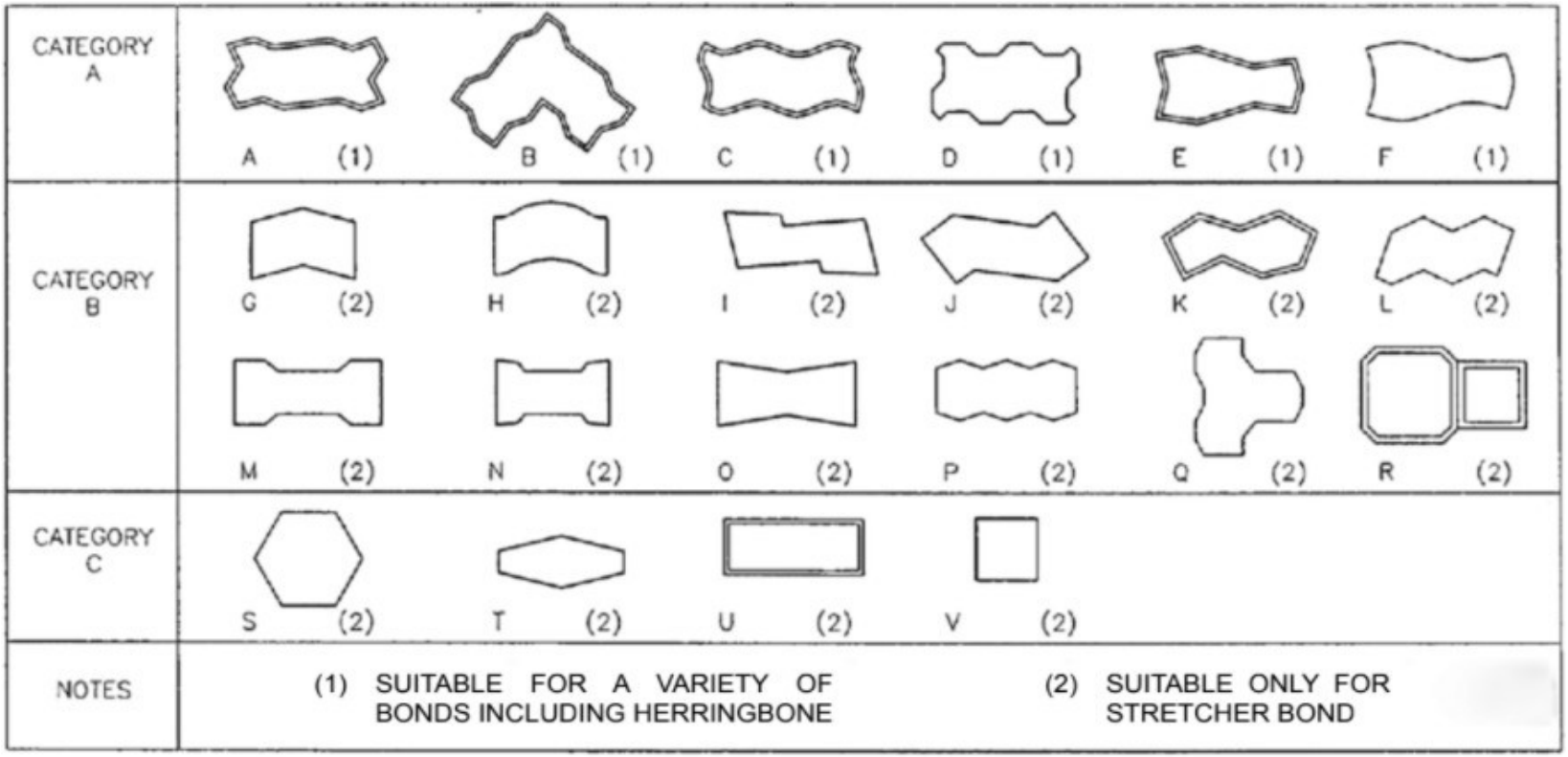


(iv) 'X' SHAPED BLOCK FOR BETTER INTERLOCK AND FASTER MECHANISED PAVING

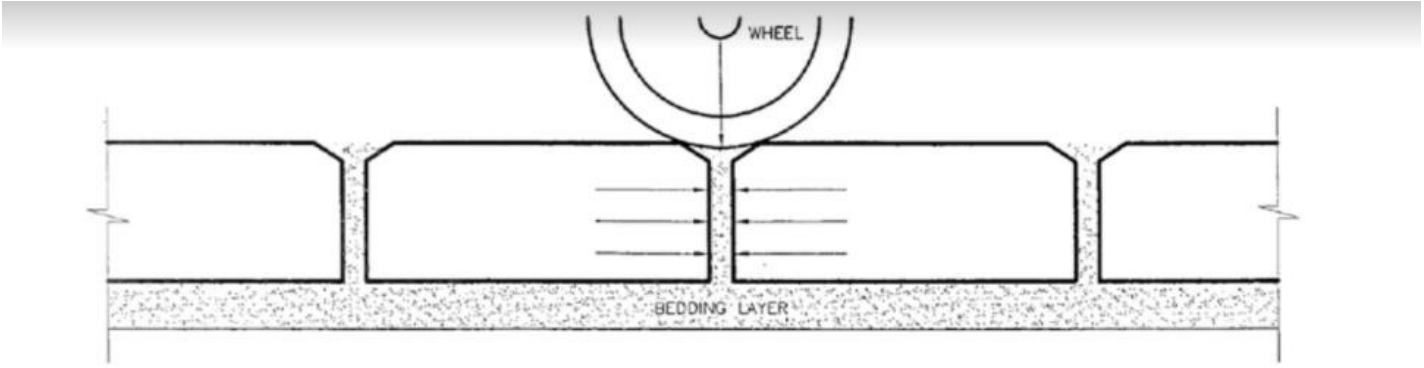
Laying patterns for interlocking concrete block pavements



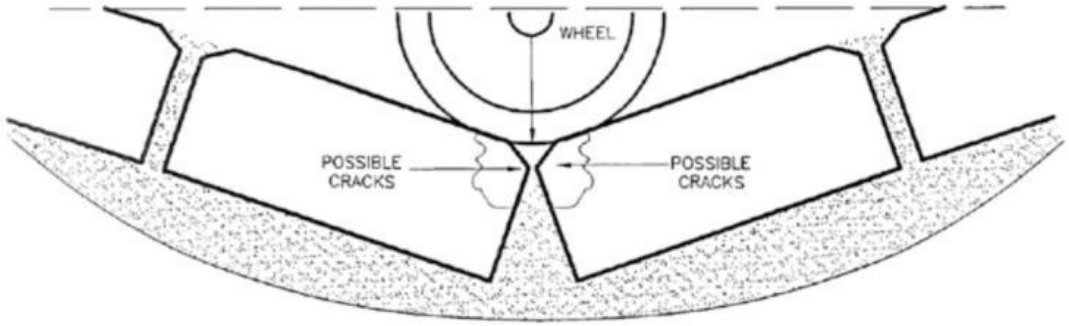
Category of ICB



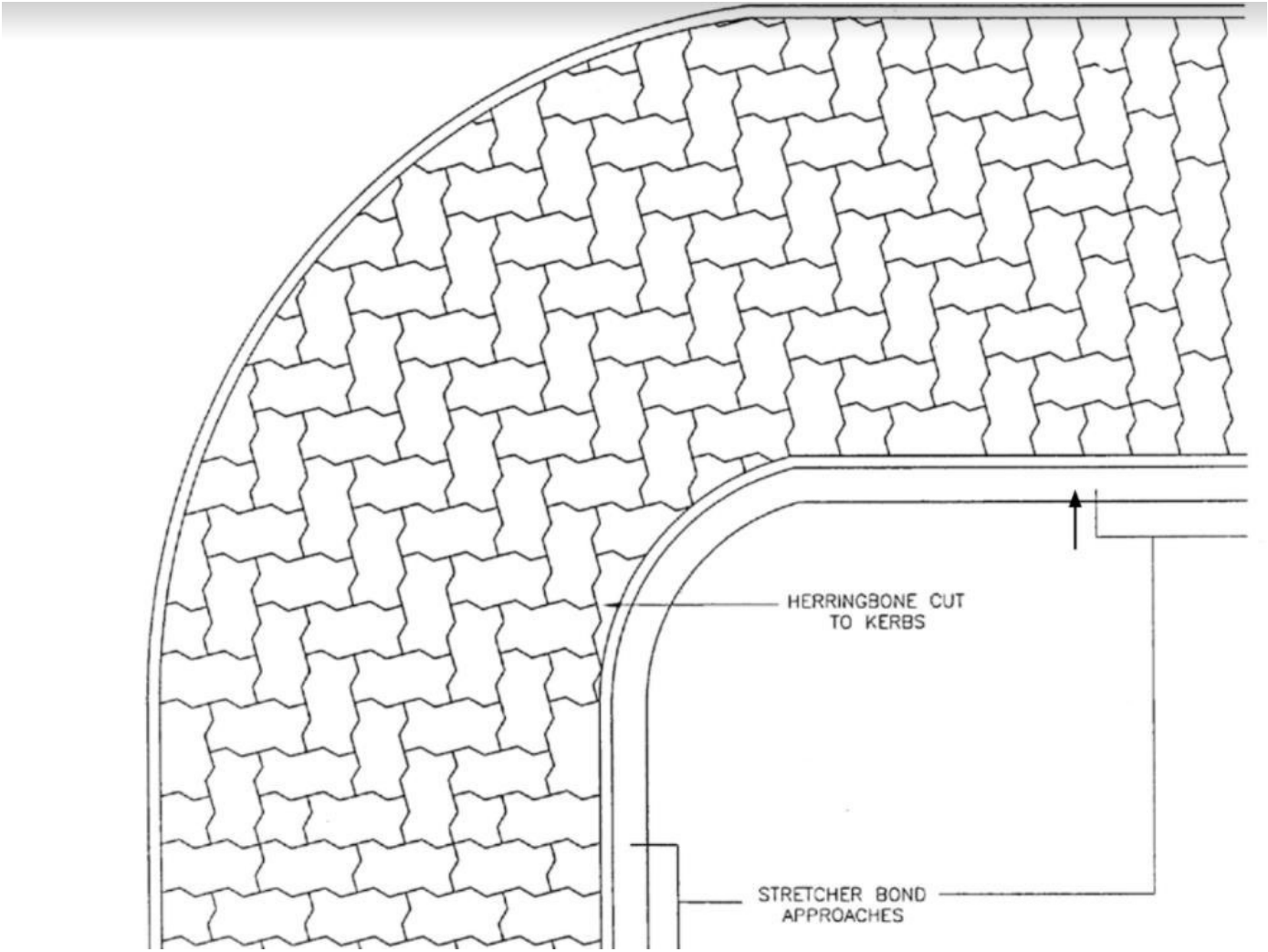
Need for jointing sand



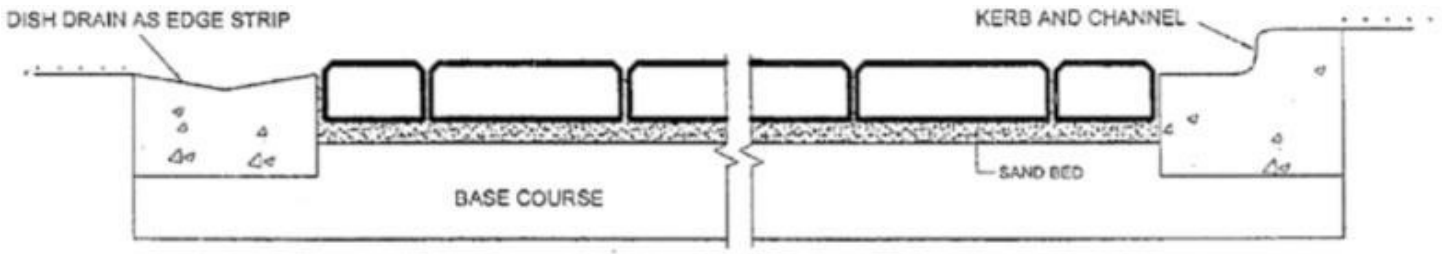
(A) SAND-FILLED JOINT SPREADS WHEEL LOAD



Laying patterns of the ICB pavement near curves



Edge blocks as restrain



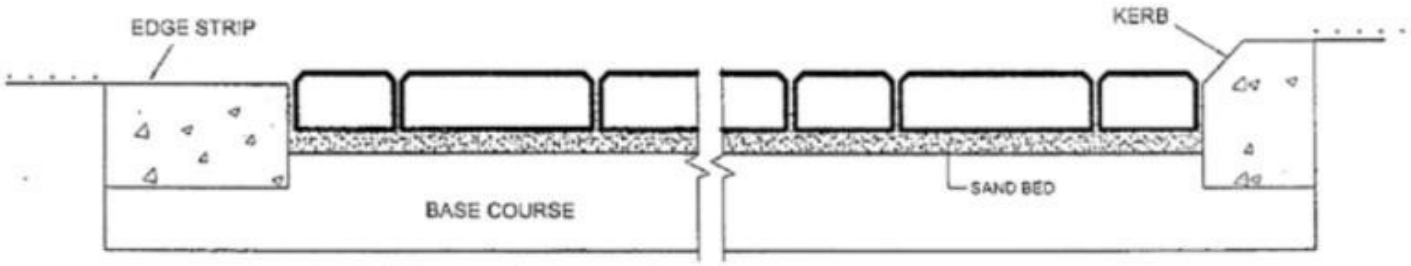
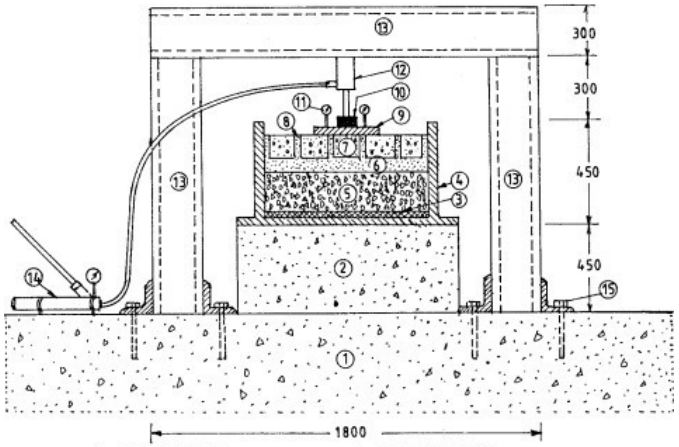


Plate load test studies

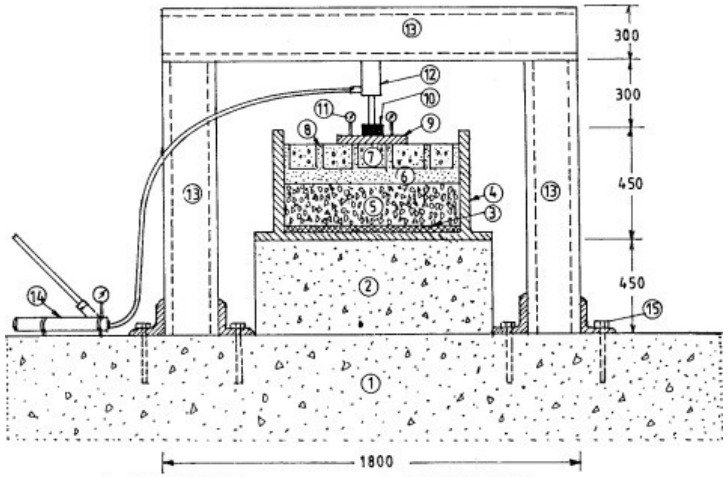


1. P. C. C. FLOOR
2. P. C. C. PEDESTAL
3. RUBBER SHEET
4. TEST BOX
5. CRUSHED ROCK SUB-BASE
6. BEDDING SAND
7. CONCRETE BLOCKS
8. JOINTING SAND
9. LOADING PLATE
10. LOAD CELL
11. DEFLECTION GAUGE
12. HYDRAULIC JACK
13. REACTION FRAME
14. PUMPING UNIT
15. ANCHOR BOLTS

Sieve size (mm)	Zone I, % passing	Zone I ⩾2.36, % passing	10% Zone I ⩾2.36, % passing	15% Zone I ⩾2.36, % passing	Zone II, % passing	Zone II ⩾2.36, % passing	Zone III, % passing	Zone IV, % passing	Crushed rock subbase material, % passing
				(a) Gradation					
20	—	—	—	—	—	—	—	—	100
10	100	100	100	100	100	100	100	100	77
4.75	94	100	100	100	100	100	100	100	66
2.36	70	100	100	100	88	100	98	99	50
1.18	46	65.71	68.23	70	72	81.81	89	94	34
0.60	30	42.85	47.05	50	45	51.13	63	88	25
0.30	16	22.85	28.52	32.5	21	23.86	25	38	15
0.15	6	8.57	15.29	20	6	6.81	8	6	8
0.075	2	2.85	10	15	2	2.27	3	3	4
				(b) Angle of shearing resistance (ϕ)					
ϕ(°)	42.62	41.86	41.08	40.16	40.49	39.72	38.1	37.24	—

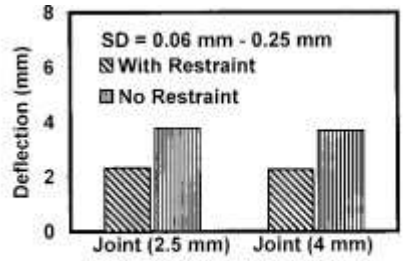
Panda and Ashok kumar, 2002

Plate load test studies

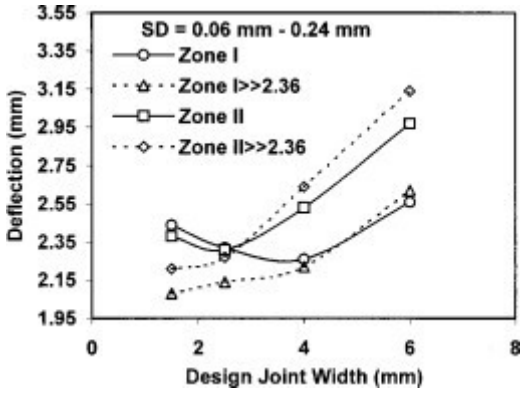


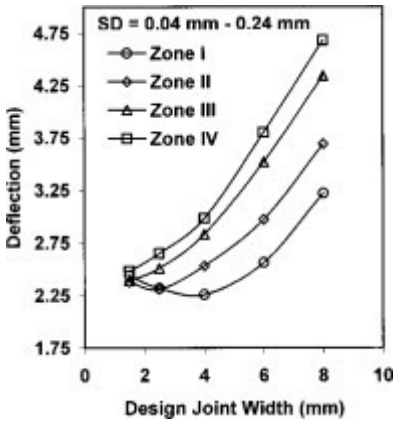
- A hydraulic jack was used to apply static load of 51 kN on a rigid circular plate of 300 mm diameter
- Parameters investigated: Joint width, thickness of bedding sand, Quality of bedding sand, with and w/o edge restrain
- Deflection was the parameter which was observed in the test

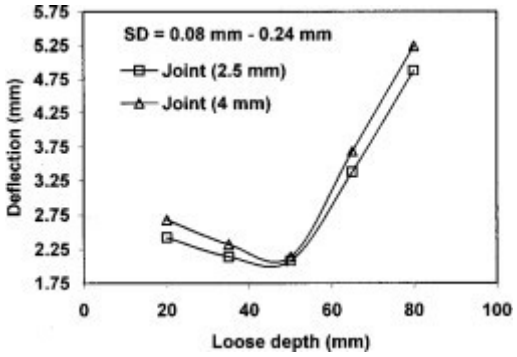
Plate load test studies



Pavement deflections with and without edge restraint







Catalogue for layer thickness – IRC SP63-2014

Table 1 Design Catalogue for Pavement Thickness

Traffic and Road Type	Types of Layers	Subgrade CBR (%)		Grade of Block
		Above 10	5-10	
• Cycle Tracks, Pedestrian Footpaths	Block Thickness Sand Bed Granulated Subase	60 mm 30±5 mm 200 mm	60 mm 30±5 mm 200 mm	M-30
• Commercial Traffic Axle Load Repetitions less than 10 msa • Residential Streets	Block Thickness Sand Bed WBM/WMM Base Granular Sub-base	60-80 mm 30±5 mm 250 mm 200 mm	60-80 mm 30±5 mm 250 mm 250 mm	M-40
• Commercial traffic Axle Load Repetitions 10-20 msa • Collector Streets Industrial Streets, Bus and Truck Parking Areas	Block Thickness Sand Bed WBM/WMM Base Granular Sub-base	80-100 mm 30±5 mm 250 mm 200 mm	80-100 mm 30±5 mm 250 mm 250 mm	M-40
• Commercial traffic (Container yard and see ports) Axle Load Repetitions 20-50 msa • Arterial Streets	Block Thickness Sand Bed WBM/WMM Base or WBM/WMM Base and DLC over it* Granular Sub-base	100-120 30 ±5 mm 250 mm 150 mm 100 mm 200 mm	100-120 30 ±5 mm 250 mm 150 mm 100 mm 250 mm	M-50

Bedding sand Jointing sand gradation

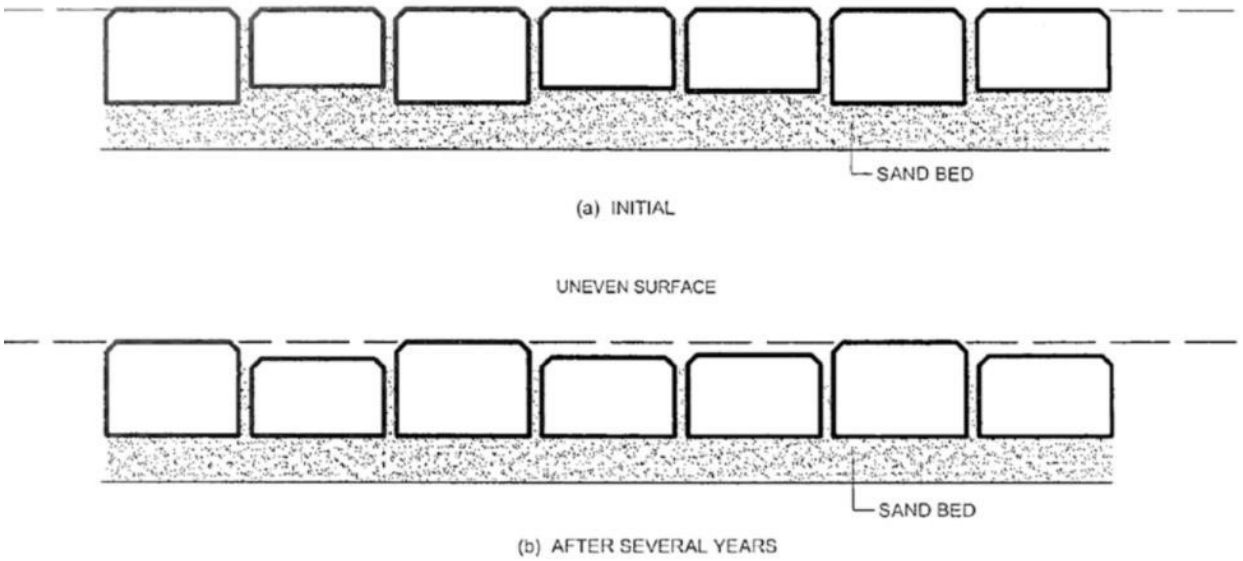
Bedding Sand gradation

IS Sieve Size	*Per cent Passing*
9.52 mm	100
4.75 mm	95-100
2.36 mm	80-100
1.18 mm	50-95
600 micron	25-60
300 micron	10-30
150 micron	0-15
75 micron	0-10

Joint Filling Sand gradation

Sieve Size	*Per cent Passing*
2.36 mm	100
1.18 mm	90-100
600 micron	60-90
300 micron	30-60
150 micron	15-30
75 micron	0-10

Implication of non-uniform thickness of the blocks



Non-uniform thickness of the blocks affects the evenness of the surface. Maximum allowable tolerance is ± 2 mm

Construction

- Similar to any other flexible pavement the process involves the compaction of subgrade, sub-base and base
- Bedding sand of defined gradation having a thickness in loose form of 25-50 mm is compacted to 20-25 mm using plate vibrators weighing 0.6 T or more
- Edge restraints should be established before laying the blocks
- Once the blocks are laid (the blocks should not be tightly laid, a spacing of 2 – 4 mm is desirable), vibratory plate compactors are used over the laid blocks
- The joint filling sand are spread over the block surface and are filled into the joints using broom

Common failures observed in interlocking concrete block pavements

Advantages and Limitations of ICBP

Advantages

- ICBP does not require curing (unlike other concrete pavements), and can be opened immediately to traffic after construction
- Requires less sophisticated equipment
- The system provides ready access to underground utilities
- Low maintenance cost and a high salvage value ensures a low life cycle cost

Limitations

- Quality control of the blocks at factory premises is a prerequisite for durable 'ICBP'
- Any deviation in base course profile will be reflected on ICBP surface.
- High quality and gradation of bedding sand and joint filler sand are essential for good performance
- Poor drainage condition of granular base course can lead to faster deterioration
- Not suitable for high speed roads