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New Materials and Technologies for Rural Roads

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Innovations in Materials and Construction Practices

- Thanks to the initiatives taken by NRIDA and NHAI during the last one decade, numerous new materials and construction and rehabilitation techniques have been used in low volume roads extensively under PMGSY programme and in some sections of NHAI
- Some of the new technologies used to reduce cost and quantities of materials consumed:
  - Technologies in which different layer materials are water-proofed reducing their moisture susceptibility
  - Chemical stabilization of subgrade and granular materials
  - Geo-synthetic materials for reinforcement and drainage
  - Modified binders
  - Use of waste plastic in dry process
  - Cold mixes
  - Different forms of concrete pavements with shorter joint spacing (pre-cast as well as cast-in-situ)

Innovations in Materials and Construction Practices

- Thanks to the initiatives taken by NRIDA and NHAI during the last one decade, numerous new materials and construction and rehabilitation techniques have been used in low volume roads extensively under PMGSY programme and in some sections of NHAI
- It is essential that the suitability or otherwise of these technologies is reviewed based on some key considerations.
  - ✓ Performance
  - ✓ Identification of critical failures and the layers which fail
  - ✓ Availability of materials
  - ✓ Ease of construction
  - ✓ Durability of materials
  - ✓ Recyclability of materials
  - ✓ Ease of maintenance and rehabilitation
  - ✓ Availability of tools for analysis of new forms of pavements

Performance

- All roads are built to satisfy the functional requirements of users: comfort, safety and economy.
- Comfort: is influenced by the variation (mostly along the wheel paths) in the profile of the road the he pavements of roads.
- While travelling on roads, different parts of the vehicles, drivers and passengers are subjected to three dimensional displacements, velocities and accelerations.
- On the other hand, vertical acceleration of the abdominal cavity has been identified as one of the critical parameters affecting the comfort of persons travelling in vehicles.

Performance

- Discomfort is maximum at or near a frequency of 5 cycles/s. As the vehicles travel along a road, variation in the surface profile (levels) along the paths of the wheels affect the comfort (which is inverse of roughness, a parameter commonly used to quantify the surface condition of the roads).
- Formation of depressions, pot holes formed due to cracked layers or moisture damaged layers, differential settlement (faulting) of blocks/slabs in concrete pavements also add to roughness (discomfort)
- Cracking and plastic deformation are the main modes of structural failures the pavement layers undergo and are caused by traffic loads and climatic parameters (temperature and moisture)

Primary modes of structural failures

- It is necessary to maintain adequate structural soundness of different pavement layers during the service life of the pavement so that the resulting stress/strain levels in each of the pavement layers are small enough not to cause excess cracking or plastic deformation.
- Different layers are susceptible to different modes of structural failures.
- Subgrade – Plastic deformation
- Unbound aggregate layer (subbase and base) – plastic deformation
- Cemented bases – cracking and afterwards plastic deformation
- Bituminous layers – plastic deformation and cracking (low temperature as well as fatigue cracking
- Cement concrete – cracking, faulting of slabs
- Block pavements, cell-filled concrete pavements, granular layers stabilized/modified using different commercial stabilisers ?????

Three different Concrete Pavements

- The key features of three different types of concrete pavements are discussed here.
  - Short-panel concrete pavement
  - Cell-filled concrete pavement (cast-in-situ)
  - Interlocked concrete block pavements (pre-cast)

Three different Concrete Pavements

- Besides traffic loads, moisture is the main contributor to the damage of conventional flexible pavements with subgrade, granular layers and thin bituminous surfacing
- Owing to paucity of funds and other practical difficulties, adequate surface and sub-surface drainage measures such as raising the subgrade above high water level, day-lighting the granular subbase (drainage) layer, cannot be taken
- It is well known that concrete is less susceptible to moisture damage
- However, the thickness of concrete slab designed as per IRC:SP-62 for typical low volume traffic and temperature gradient (for contraction joint spacing of 2.5 to 4.0 m) usually is 170 to 200 mm

Three different Concrete Pavements

- The panel size varies from 4.5 m x 3.5 m (or 4.5 x 4.0 m or 4.5 m x 4.5 m) for highways to 2.5 x 2.5 to 4.0 m x 4.0 m to much smaller size.
- The size of cast-in-situ concrete slab/panel depends on longitudinal and transverse joint (grooves cut to one-third depth of slab) spacing
- If the contraction joints are not activated (crack does not form below the groove), the actual size of the slab will be much larger

Three different Concrete Pavements

- Concrete pavement will be an ideal choice if the thickness of the slab can be reduced with the resulting reduced initial cost
- However, since larger panels distribute load primarily in flexure mode, large slabs cannot be constructed thin
- For reducing the slab thickness, it is necessary to reduce the size of the slab or reduce the joint spacing
- As the joint spacing reduces from large panel size (4.5 m x 3.5 m) to small block size (0.15 m x 0.15 m), the mode of load transfer shifts from flexure to more direct compression.

Three different Concrete Pavements

- For smaller slabs, flexural stresses in the slab will be reduced and the compressive stress on the foundation layers will increase.
- Similarly, the flexural stresses associated with the temperature gradient within the slab also reduce with reduction in the size of the slab.
- Thus, reducing the size of the concrete slab is an important step for making concrete pavements a more acceptable choice for low volume roads on account of the reduced slab thickness.
- It is, however, to be noted that the total length of joint to be constructed and maintained increases as the slab size is reduced.

Three different Concrete Pavements

- Since discrete slabs are created in jointed (formed by cutting grooves) concrete pavement due to the cracking of the slab below the groves, the participation of multiple adjacent slabs in sharing the load applied on a slab influences the stress produced in the slab.
- Since no dowel bars are used in the shorter concrete slab pavements for low volume roads, the transfer of load to adjacent slabs depends on the degree of aggregate interlocking along the cracks which develop at joints below the grooves.
- Thus, the load transfer across the joints becomes a key design element in jointed pavements, especially when no dowel bars are provided.
- Some critical issues related to three different short slab concrete pavements are discussed in the following slides

Short-Panel Concrete Pavements

- Contraction joint spacing of 1.0 m to 2.0 m.
- Because of the reduced slab size, wheel load bending stress and curling stress (due to temperature differential in the slab) are reduced.
- The critical positions of the axle load on the panel for top-down and bottom-up cracking depend on panel size, carriageway width, axle type and day time and night time.

Short-Panel Concrete Pavements

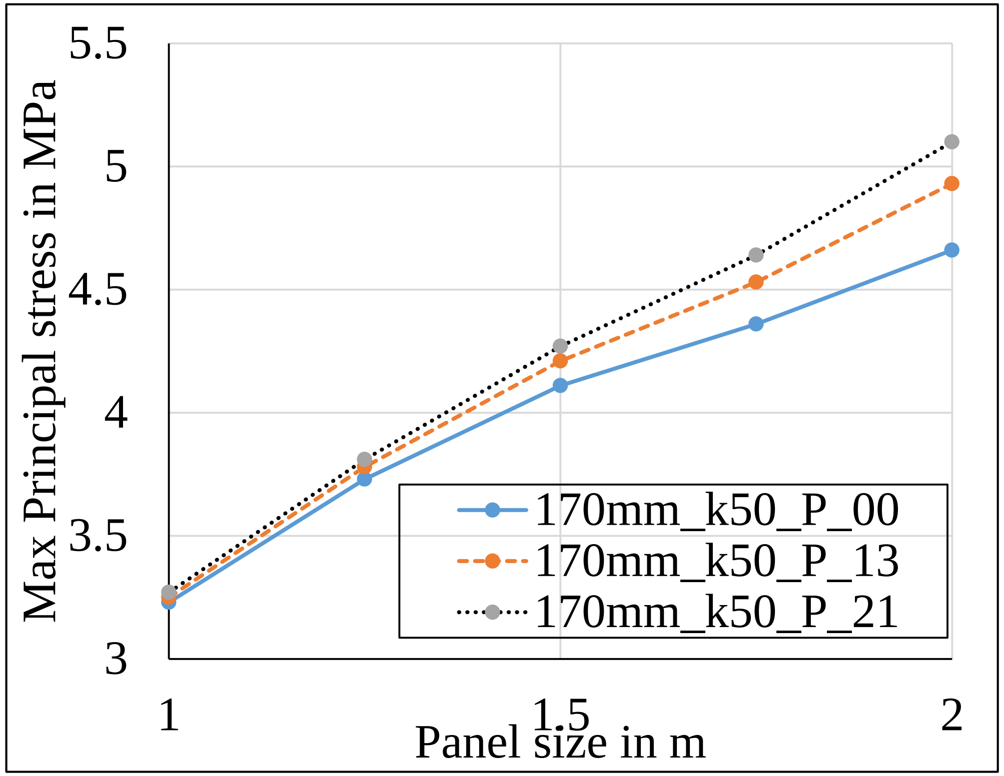
Short-panel concrete pavement on NH-18

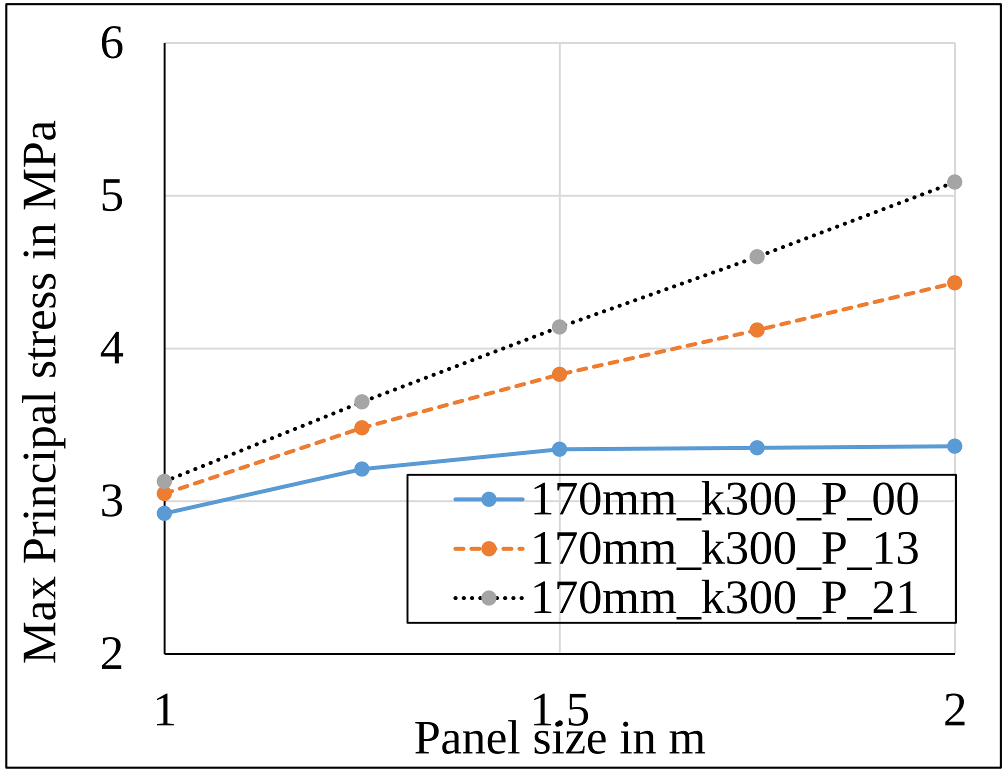
PMGSY Road in west Bengal

Short-Panel Concrete Pavements

- Joint cutting operation must be carefully planned since the total length of joints to be cut is significantly longer than that required for typical highway pavements with longer spacing.
- Joint sawing must be completed within the joint sawing window of 10-16 hours (from the time the mix is prepared), to avoid random cracking due to shrinkage stresses.
- If cracks do not form below every joint grove the resulting panel size will be much larger than designed. This may lead to cracking at irregular locations.

Short-Panel Concrete Pavements





Variation of edge flexural stress with the panel size (for a 160 kN single axle load; k = 50 and 300 MPa/; positive temperature differentials of 0, 13 and 21 °C)

Cell-filled Concrete Block Pavement

- Developed late Prof BB Pandey at IIT Kharagpur and was transferred to different agencies, finally to NRRDA.
- Based on numerous laboratory and on-site trials including accelerated testing and subsequent demonstration through various field sections.

Cell-filled concrete block pavement

Cell-filled Concrete Block Pavement

- The motivation for this technology is to provide thinner concrete pavements by reducing the joint spacing to as small as 150 mm, thereby creating slabs (or blocks) of small size.
- The reduction in the size of the slab helps in transforming the mode of load transfer to flexure to more of compression resulting in reduced wheel load and curling flexural stresses in concrete.
- The small joint spacing is created by using a formwork of plastic cells into which concrete is placed. This pavement is, in fact, a cast-in-situ interlocking concrete block pavement.

Cell-filled Concrete Block Pavement

- It is important that the load placed on one block or a set of blocks is shared by some additional adjacent blocks so that the stresses on the underlying layer are reduced.
- The area of foundation over which the load is distributed in a cell-filled concrete block pavement depends on the interlocking created between adjacent blocks.
- Blocks with vertical faces do not have any interlocking and hence there will be no transfer between blocks.

Cell-filled Concrete Block Pavement

- Hence, it is most crucial for the success of the cell-filled concrete pavements, to create interlocking between the blocks.
- This is done by selecting the stiffness of the plastic sheet used to prepare the plastic cell formwork within a suitable range so that the walls do not collapse while placing the concrete but bend enough to form irregular vertical faces and thereby generate aggregate interlocking.
- If too stiff plastic sheet is used and the blocks form with vertical faces, there will not be any significant load distribution of the cell-filled concrete layer.

Cell-filled Concrete Block Pavement

- The main mode of failure of this type of pavement will be the permanent deformation of the foundation.
- The structural design of the pavement can be done by considering the rutting performance criteria used in the Indian Roads Congress guidelines for flexible pavements (IRC:37, 2018) with an appropriate reliability level.
- An effective elastic modulus of 2000 MPa is recommended for the cell-filled concrete layer.

Interlocking Concrete Block Pavements

- Interlocking concrete block pavements (ICBP) have been in use in India for a long time IRC:SP-63 (2018).
- The only issue that needs to be highlighted is that the layer of blocks should be capable of distributing the load over wider area so that the stresses over the foundation layers are reduced to acceptable levels.
- Hence, it is necessary that there has to be some interlocking mechanism between adjacent blocks of the ICBP layer.
- Interlocking is mobilised by the dilating action of the jointing sand placed in the joint gaps between blocks.
- Optimal mobilisation of the interlocking mechanism of interlocking can be achieved by strictly adhering to the joint gap, gradation of jointing sand and the gradation of the bedding sand

Concluding Remarks

While adopting innovative materials and technologies, it is essential to understand the key design or construction issues that make the technology work and pay special attention to them