DO IT YOURSELF

Cell Filled Concrete Pavement

Contents

Cell-Filled Concrete Pavement

1. Introduction

Under PMGSY, the rural roads network has experienced a considerable growth. The good quality roads being constructed, immensely contribute in the progress of the country. Most of the low volume village roads being constructed are flexible pavements provided with a thin bituminous surface. Quite often, these roads get damaged due to overloaded vehicles, inadequate drainage facility and water logging problems, and hence require early periodic maintenance. Also, in the absence of adequate fund and timely maintenance, the serviceability level of the roads deteriorates rapidly. Therefore, to there is a need to come up with new innovative technologies, developed through Research and Development Initiatives (R & D), which lead to creation of durable assets, reduces the maintenance cost and enhances the employment opportunities in rural areas. The technology developed by IIT Kharagpur, known as Cell filled Concrete Pavement, has proved to be very promising solution for the above mentioned issues. It provides long lasting concrete pavements (permanent asset) at low initial cost which are almost maintenance free. This also generates employment opportunities in rural areas.

2. The Concept

The technology consists of covering the compacted sub grade / sub base with a formwork of plastic cells as shown in Figure 1. The form work of plastic cells is stretched and iron spikes are driven at the corners of the cells so that the form work remains taut. Nylon ropes through the cell walls prevent collapse of the cells during the placing concrete or stones into the cells. The plan of the formwork will appear as shown in Figure 2 on stretching.

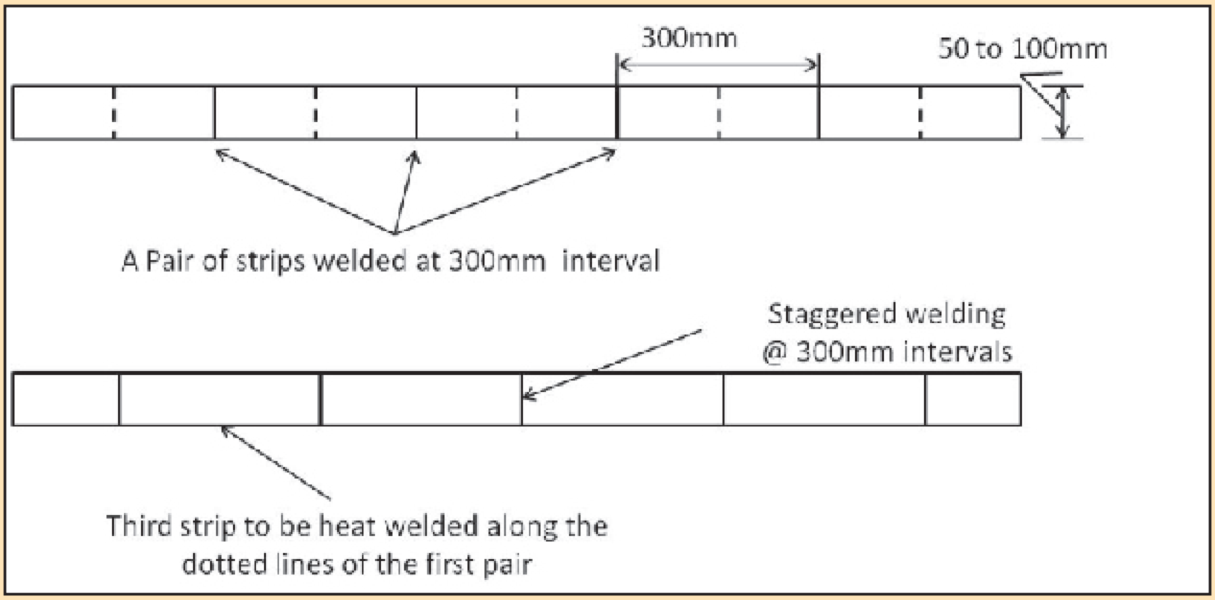


Figure 1 Welding and stitching of plastic sheet strips at 300 mm interval

Figure 2 A view of stretched cell placed over compacted GSB layer

Different types of concrete such as conventional concrete/ zero slump concrete with a 28 day characteristic strength of 30 MPa is placed into the cells. Since the subgrade/subbase have the proper camber, the top of the cells also will have the same camber. After leveling the concrete, a vibratory/ static road roller of 6 to 8 ton capacity may be used for compaction. One or Two static passes followed by two vibratory pass and again one or two static pass will bring about the necessary compaction. The exact number of passes will depend upon the angularity of aggregates and trials have to be made to determine the number of passes. Static rolling with more number of passes may bring about the necessary compaction because of lower thickness. The cell walls get curled both vertically and horizontally during the construction to bring about the three dimensional interlocking among the concrete blocks as shown in Figure 3.

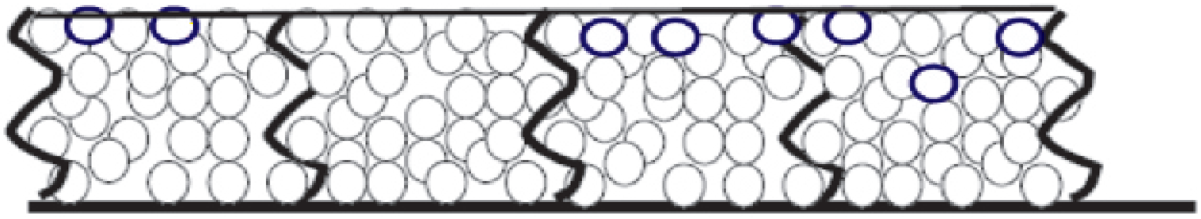


Figure 3 Interlocking of blocks

Normal concrete of required strength having a slump of about 30 mm to 50 mm can also be poured into the cells and vibrated with a pan vibrator. The cell walls deform during the placement due to vibration and develop interlocking. The surface should have the camber of 2.5 to 3.0%. Trials should be made to work out the logistics before starting the actual construction. Some aggregates may absorb moisture and on hot sunny days, evaporation loss may be quite high during mixing, transportation and placing and water is to be accordingly adjusted. The subgrade/subbase should be moistened so that water is not drawn to it from concrete.

3. Plastic cells

Form work of plastic cells can be made from reclaimed high density polythylene (HDPE) sheets of thickness 0.22 mm to about 0.25mm. Plastic sheet manufacturers can supply rolls of strips 50mm to 100mm wide depending upon the depth requirement. The strips can be heat welded or stitched to form cells as shown in Figure 1. Colour of plastic sheets is not important since the cells remain buried and reclaimed HDPE/LDPE sheets are usually rendered black in colour. Waste lo w density polyethylene (LDPE) is available in plenty and the recycled LDPE sheets of thickness 0.30 to 0.35 mm can be used for making the form work of cells. Readymade form work of cells also can be obtained from the market.

A pair of strips can be welded at 300 mm interval. The third strip is welded to the first pair at 300 mm intervals so that the stitch lies at the centre of the previous stitching. The third and the fourth ones are again welded like the first two. Figure 4 shows the plan of a cell. Dimensions of the sides can vary from 150mm to 200mm.

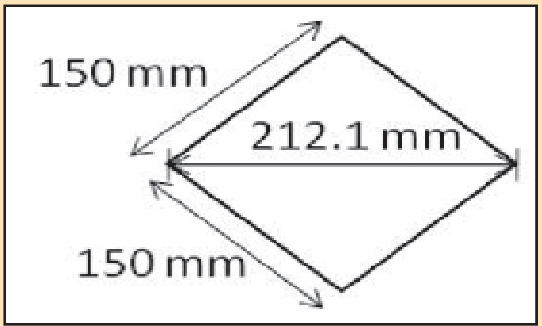
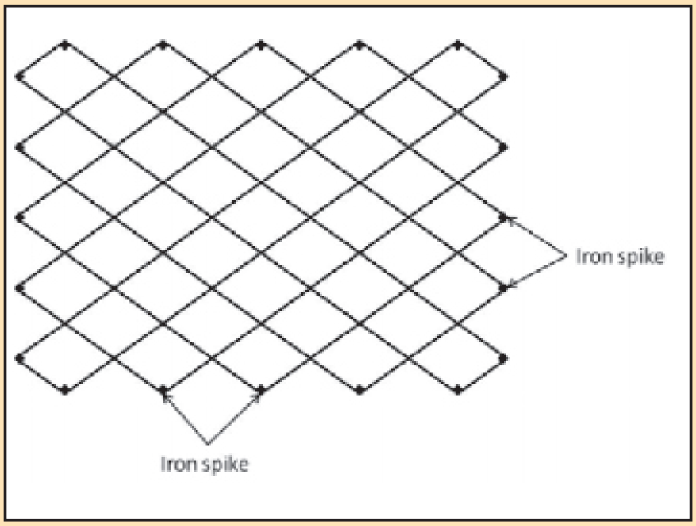


Figure 4 View of a plastic cell in plan

Iron spikes of about 200 mm long as shown in Figure 5 are used to keep the cell walls taut. Nylon threads are used for preventing collapse of cell walls during the placement of concrete. The spikes are to be taken out for use at other places as soon as concrete is filled into the cells. Nylon threads also can be taken out after the placement concrete. The quantity of plastic sheets of thickness 0.22 mm, side 150 mm and depth 100 mm will be nearly 1250 kg for a road 3.75 m wide and 1 km long. Formwork of cells should be so stitched that one roll of cells for a pavement width of 3.75 m has a length of about 10 to 20 m upon stretching. The successive rolls of cell can be stapled for pavement construction. LDPE sheets may weigh more because of greater thickness requirement for stiffness.

A



B

C

Figure 5 Tightening of plastic cells using Iron spikes and nylon threads

4. Preparation of Subgrade

The subgrade forms the top 300 mm thick portion of the embankment and it should be prepared as per Specifications for Rural Roads. The subgrade in embankment is compacted in two layers usually to a higher standard than the embankment. If the embankment soil is poor, the top 300mm of the subgrade may consist of good quality material from borrow pits with CBR exceeding five. It should be compacted to at least 100 per cent of Maximum Dry Density as per IS:2729 (Part 7). The expansive black cotton soil (BCS) should be compacted to a minimum of 95% of the maximum dry density with moisture content 2% higher than the optimum. A bck cotton soil can be stabilized by lime to impart improved strength to the subgrade in addition to reducing swell and shrinkage of the soil.

The subgrade soil of existing roads is expected to have attained the required stability due to traffic and CBR test should be done at in situ dry density and moisture content after four days of soaking. Dynamic cone penetration test can be done to determine CBR values of subgrade in a short time and CBR values corresponding to soaked condition can be obtained from past records of similar soils.

5. Subbase

The subbase may consist of laterite boulder consolidation, water bound macadam, wet mix macadam, jhama brick consolidation, crusher run macadam, lime-fly ash-aggregate mixtures, lime stabilized soil, cement stabilized soil and others with proprietary stabilisers. Locally available aggregates such as murrum and kankar mixed with lime fly ash may also be used. If aggregates are not available at a reasonable price, soils may be stabilized to obtain a soaked CBR value of 20 or higher. The locally available materials such as natural gravel/soil aggregate or blended with suitable aggregate fractions of stone, gravel, moorum, sand or combination of these materials depending on the grading required. If the number of commercial vehicles is more than fifty per day, 150mm of cementitious subbase with minimum 7 day strength of 1.5 MPa is recommended. The subbase should be provided with stone/concrete block or Brick on edge should be laid on either side of the carriageway projecting 50 to 100 mm above the subgrade/subbase for the confinement and protection as shown in Figure 6 Stone/ concrete block or Brick on end edge should be laid on either side of the carriageway projecting 50 to 100 mm above the subgrade/subbase for the confinement and protection.

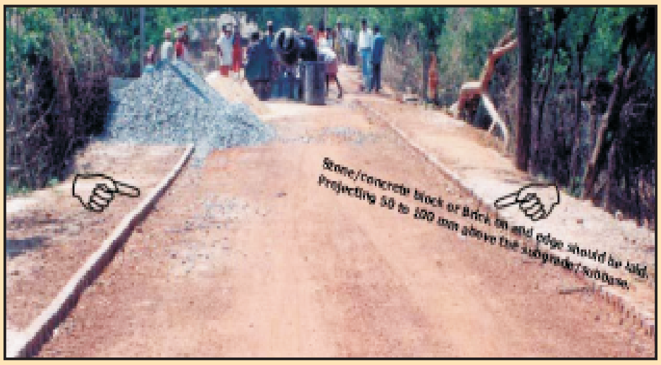


Figure 6 Stone/concrete block of Brick on end edge

6. Concrete

Conventional concrete having 28-day strength of 30 MPa with a slump of about 30 to 50mm can be used for filling up the cell. Super-plasticiser should be used to reduce water requirement for the desired slump. The Roller Compacted Concrete (RCC) as specified in clause 1502 of Specifications for Rural Roads can also be used for filling up the plastic cells and compacted with a roller. RCC should have a minimum characteristic strength of 30 MPa at 28 days since flexural strength requirement is not important in cast-in-situ bock pavement. Cement should conform to Clause 1501.2.4 of SRR. Fly ash collected by electrostatic precipitator can be used as partial replacement of OPC-53. Bottom ash and pond ash should not be used for substituting a part of cement. Fly ash should not be used as replacement of cement when pozollana or slag cements are used.

Coarse aggregates should consist of strong crushed stone or crushed gravel with aggregate impact value (IS:2386 part 4) lesser than 30 to prevent crushing due to iron rimmed animal carts so common in villages in India. The aggregates should not have flakiness index exceeding 40 percent. The maximum size of the aggregates should not exceed 26.5 mm. For very low volume roads with motorized traffic less than 50 vehicles per day, gravels from river bed or pit run gravel deposits may also be used.

Fine aggregates should consist of clean natural sand or crushed stone or a combination of the two and meet the requirement as per Specifications. Coarse and fine aggregates should be blended to obtain an Aggregate Gradation as given in Table 1.

Table 1 Aggregate Gradation for Concrete

Sieve size, mm	Percentage passing by weight
26.50	100
19	80-100
9.50	55-80
4.75	35-60
0.60	10-35
0.075	0-8

Aggregates, sand and cement should be proportioned by weight. Wooden or iron measuring boxes may be used to measure ingredients by volume after calibrating with weigh batcher. Only steel measuring box should be used for cement. A permanent mark should be made on a suitable container to allow only specified quantity of water.

7. Mix. Design

IRC:44-2008, Guidelines for cement concrete mix design for pavements may be used for normal concrete. Trials are necessary to arrive at a correct mix composition for a specified strength. Methods given in clause 1502.8 of Specification for Rural Roads may be used for mix design of Roller Compacted Concrete (RCC).

8. Construction

Construction of embankment, subgrade and subbase should be done as per Specifications for Rural Roads. Proper camber as applicable to rural roads should be provided. Drainage layer also should be provided in high rainfall area (annual rainfall exceeding 1000 mm) as laid down in Rural Road Manual. Stone/concrete block or Brick on end edge should be laid on either side of the carriageway projecting 50 to 100 mm above the subgrade/subbase for the confinement and protection of cell filled concrete of thickness, 50 to 100 mm. Laterite boulders or stabilised local materials may also be used for the confinement. Hard shoulder withpropercamberisnecessaryforthe stability of the concrete blocks since trucks travelling close to the edge may damage the unconfined concrete blocks. The width of the hard shoulder should be about 0.85 m on either side of the pavement.

Formwork of plastic cells may be laid across the compacted subbase and put under tension with iron spikes so that cells are close to squares in plan. Nylon threads passing through the cells 10 mm below the top of the cells should be used to prevent the cells from collapsing during the filling of the cells with concrete. If any stitch of the cells opens up during tensioning, it should be stapled near the top, middle and the bottom. Concrete should be filled into the cells to a depth of about 120 mm which is about 20 mm higher than the depth of the cell. Uniformity of level should be checked before the compaction. The iron spikes should be taken out after the cells are filled up with concrete. For RCC, one or two passes of the roller in static mode followed two passes in vibratory and another pass in static mode sufficient compaction and a good finish. Number of passes in static and dynamic modes depends upon the texture of aggregates and moisture content. Some amount of water may evaporate during mixing, transportation and placing during hot weather and this may result in a dry mix. Additional water may have to be added during the mixing in such cases, walk behind vibratory roller and vibratory plate compactors/earth rammer may also be used for compaction of concrete. Small rollers are easy to manoeuvre in narrow village roads. Pan vibrators can be used for the compaction of the conventional concrete having a slump of about 30 to 40 mm. The pictorial view of the construction procedure carried out at site is presented in figure 7.

Figure 7 A pictorial view of construction procedure carried out at site

A trial stretch 15 m long should be constructed close to the road before commencement of actual construction to sort out various logistics. Number of passes of roller, amplitude of vibrations, the depth of loose concrete in cells and the amount of water to be added can be determined from the trial run. Allowance for moisture in aggregates and sand must be made while adding water during mixing.

If the compacted surface of pavement appears to be too dry, additional water should be, added during mixing. The surface of the concrete should be covered with wet jute mats or paddy straw after the construction to prevent drying during hot weather. If some hungry surface or honeycombed concrete is visible after rolling, moist cement-sand mortar 1:4 should be broomed-in and one pass of roller in static mode should be given. In some places, finished level of concrete may be a little higher than the level of plastic cell after compaction. After passage of traffic for some time, pattern of the cells will reflect on the surface in the form of cracks. At some locations, the finished concrete level may be lower than the top of the plastic cell. The projecting part of the plastic may wear away in course of time due to traffic.

Roads in hilly terrain may have high longitudinal gradients and the cast-in-situ blocks may slip over the subbase. Under such condition, transverse grooves 250 mm wide and 200 mm deep as shown in Figure 9 should be made at 15 m to 20 m intervals so that the concrete in the groove as well in the cells are bonded preventing slippage along the longitudinal direction.

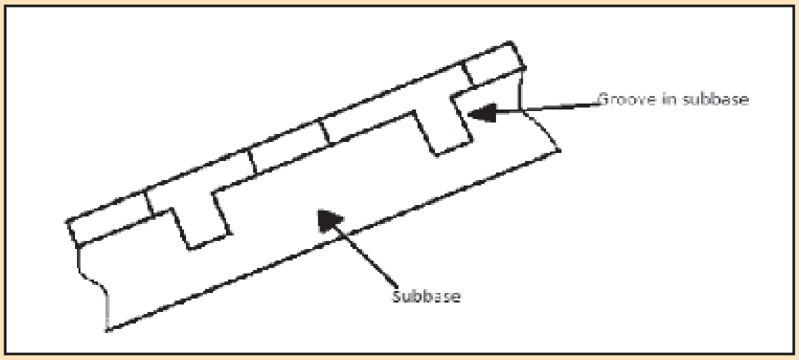


Figure 8 Typical arrangement for Construction in Hilly Terrain

Material, Machinery and Labour Requirement

- 200 micron plastic sheet- 1 Kg = 28 meter long of 10 cm width - (1.75 Sq.m/Kg - 214 Kg for 3.75mx100m)
- Labour-approximately
- Male workers-20
- Female workers-7

Mason-4

1 number concrete mixer

15 mm needle vibrator-1 no.

Plate or screed vibrator-1 no.

Mechanical trowelling-1 no.

Max. 25 meter length (of width 3.75 meter) can be laid in a day (about 10 cum of CC)

9. Joints

Since the concrete is in the form of blocks of size 150 mm x 150 mm with plastic sheets on the vertical interfaces, *no joints are necessary*. The concrete blocks would shrink during curing causing a gap of about 20 microns between two neighbouring blocks, which should be able to accommodate the expansion of concrete. Joints are, therefore, not necessary in the construction. The last group of blocks cast at the end of the day may become weak if care is not taken. *Aggregates of size 40-50 mm should be filled into the last group of cells shown as shaded ones before compaction of concrete in the earlier cells*. Before commencement of work the next day, the aggregates should be taken out from the cells and filling of concrete into the plastic cells should commence after spreading another roll of cells. Figure 9 shows a typical arrangement for preparing the formwork.

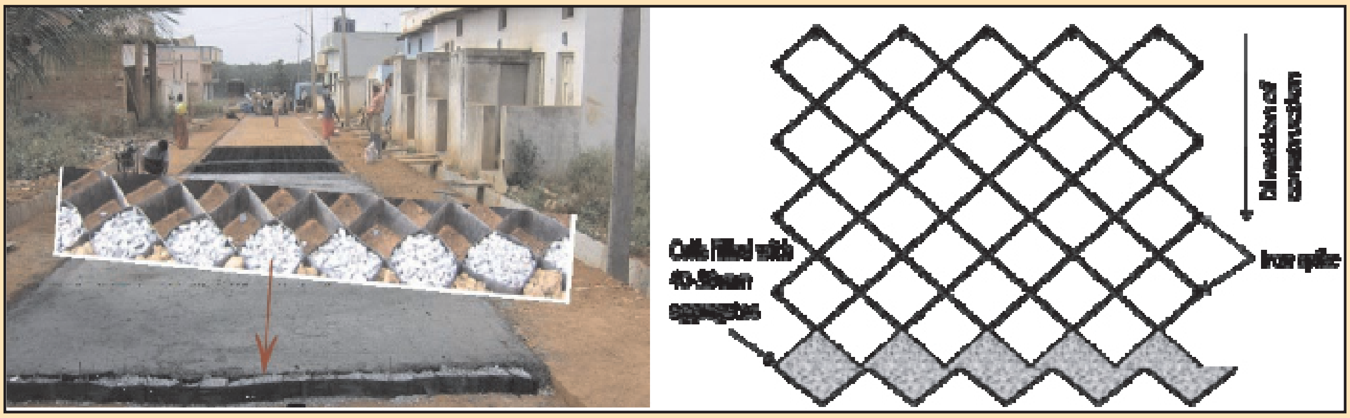


Figure 9 Aggregates filling in the last group of cells

10. Quality Control

A minimum of three cubes should be cast everyday from field mi•es for the evaluation of strength of the mi•es after 28 days. Homogeneity of concrete should be determined from cores. Interlocking of blocks can be easily seen in the cores taken at the interface separated by the plastic sheet.

11. Curing

Because of camber of about 3 to 3.5 % specified for rural roads, wet jute/coir mats and wet paddy straw (figure 10) provide better water curing option and light traffic can be allowed to move on the surface. In water ponding method, water accumulates on the lower side of the mud enclosure whereas the higher part becomes dry soon.

Figure 10 Curing of concrete by wet paddy straw and ponding

12. Opening to traffic

Concrete surface can be *opened to light traffic* such as bi-cycle, rickshaw, motorcycle etc *after two days of curing*. Iron rimmed bullock carts and *heavy traffic* like bus, truck, tractor etc can be permitted *after 14 days* when concrete is sufficiently strong.

13. Appearance of Top surface

Figure 11 shows the appearance of the top surface of the pavement. The outline of the plastic formwork is clearly seen. The formwork of cells 100 mm deep may not always be visible if concrete thickness is more than 100mm at some locations. Cracks would form at the locations of the plastic sheets showing the pattern of the formwork of plastic cells after application of traffic for some months.

Figure 11 Appearance of Top Surface of Cell-Filled Pavement

14. Grouting method of Construction of flexible concrete pavement

This grouting method of construction can also be used in construction. If the flakiness index of the aggregates is less than 30 %, a method of construction described in the following can be used to simplify the process of pavement construction. The formwork of cells are spread over the compacted subgrade /subbase and kept taut as mentioned in cls.3 and 8. The cells are uniformly filled up with single size aggregates of nominal size 20mm/ 26.5mm and rolled with a 8 to 10 ton road roller. Cement: sand slurry mixed in the ratio 1: 1 by volume is vibrated into the compacted aggregates by a pan vibrator. *Cement should be mixed with water first and then sand should be added for making a slurry.* This method of mixing gives a higher strength Quantity of water for slurry making will depend upon the angularity and absorption characteristics of aggregates, air temperature and wind velocity. For most application, a water cement ratio of 0.45 to 0.5 produces a mortar which can penetrate into the voids of mineral aggregates and but full depth penetration of mortar takes place only when aggregates have flakiness index less than 30%. Super plasticiser will provide lower viscosity to the mortar facilitating easy penetration. River and pit run gravels are usually non-flaky and complete penetration of mortar is ensured because of rounded surface of the aggregates. Low speed and low volume of traffic is not likely to pose any safety problem from skidding consideration even when rounded aggregates are used. Cement- sand mortar does provide friction to the road surface. Construction cost would be much lower than that where crushed aggregates from far away sites are used. Thickness of concrete blocks may vary from 50 mm to 100 mm depending upon the traffic. Laboratory Tests indicate that 28 day cube strength of concrete by grouting method can be close to 25 MPa or higher. If bigger size Hand broken aggregates are used, the cells are first filled with coarser aggregates and then cement-sand slurry is poured. 11.2 mm aggregates are then placed in the voids of the bigger aggregates and rolling is carried out. More cement-sand mortar is poured over the surface and vibrated. A final pass of a roller will give a good riding surface.

15. Pavement thickness of flexible concrete

These pavements will usually consist of an unbound granular subbase or cement treated granular or soil layer and a surfacing of cell filled flexible concrete surface. If the CBR of the subgrade is five or more, no subbase will be necessary from structural consideration for low volume road with motorized traffic including tractors and tractor trailer less than 50 per day, but a minimum thickness of 100mm is necessary to provide a non-erodible support.

The thickness of granular subbase (GSB) for 75 mm and 100 mm cell filled concrete surface for different equivalent standard axle load repetitions are shown in Figures 12 and 13. It is based on subgrade strain criterion. 100 mm is the minimum thickness of granular subbase for the safety of the cell filled concrete pavement. The subbase also acts as a platform for the construction of cell filled concrete pavement. In case the GSB is not available, lime stabilized soil, cement stabilized soil or lime-fly ash stabilized soil also can be used as subbase.

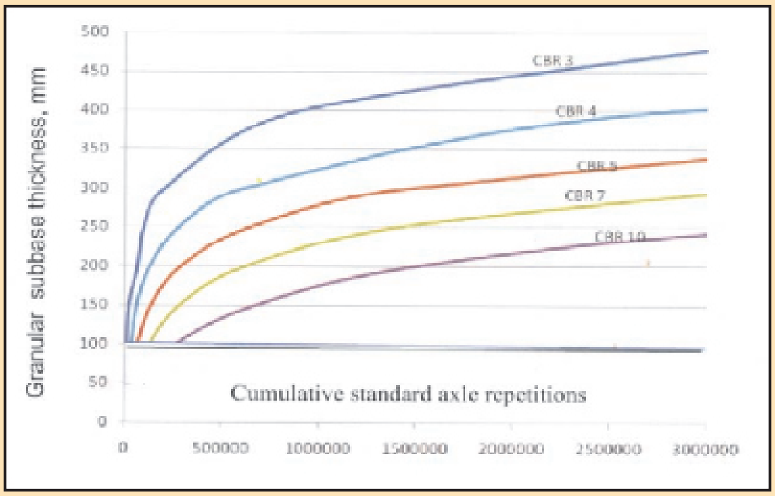


Figure 12 Thickness chart for granular subbase for 75mm thick Cell-filled concrete layer

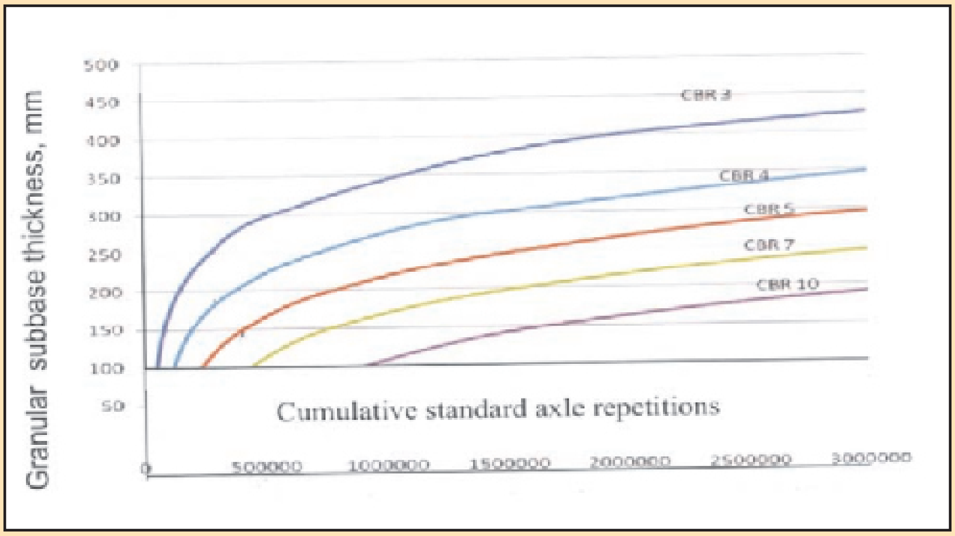


Figure 13 Thickness chart for granular subbase for 100mm thick Cell-filled concrete layer

16.0 Advantages of Cell Filled Concrete Pavements

- Use of recycled plastic.
- Expansion or contraction joints are not required and hence Maintenance of joints is eliminated.
- The cost of construction is considerably reduced when compared to conventional cement concrete pavement.
- The consumption of aggregates is almost reduced to 50% when compared to normal CC pavements.
- Due to high stiffness, the overall crust requirement gets reduced hence economical for low volume of roads.
- If the individual block fails, then it can be easily replaced without much effort and with least cost.

Disadvantages of Cell Filled Concrete Pavements

- The preparation of the cells is cumbersome.
- The cells gets disturbed while placing the concrete and hence proper care is required.
- Placing of the concrete without disturbing the cells slows down the progress.
- Consumption of labour is more, more labour oriented work.
- Due to slow progress, the actual turn out of the men and machinery is less than the normal construction.

- The cost of providing Kerb is additional and is time consuming.
- Possibility of formation of cold joints between two successive concrete layers leads to failure (as observed in Karnataka) requires treatment at cold construction joints.

17.0 Quality Tests after Construction

- Destructive testing-Extracting core after casting and test for the quality.
- Non destructive testing-By visual observations for blow up, corner breaks, cracking, faulting, pumping etc.
- Benkel Beam Deflection test
    - Deflection measurements taken at
        - 0.9m from the edge for the main road of width 5.5m
        - 0.6m from the edge for other roads of width 3.75m
    - Deflection measurements are taken at every 100m interval
    - An axle load of 8.2 Tons and tyre pressure of 5.6kg/sqcm

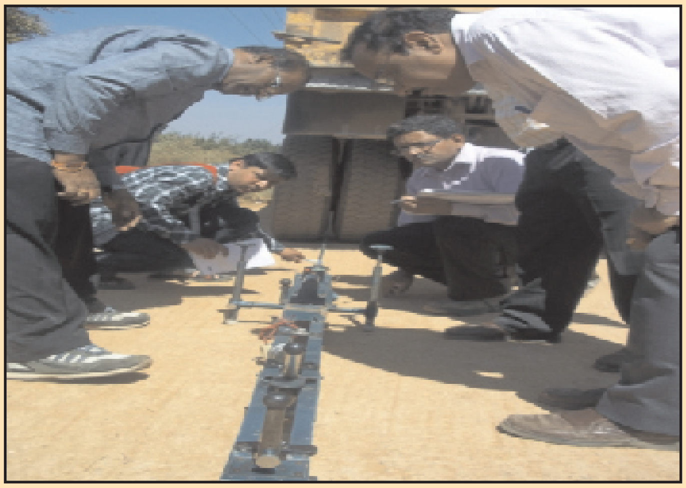


Figure 14 Quality testing after construction by core extraction and Benkel Beam Deflection test

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