Study on Failure of Interlocking Pavements

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Abstract - *Interlock pavements are a modern day solution for less cost outdoor applications and fast modes of construction practices. Interlocking concrete pavements are mostly used in countries where conventional type of construction is less durable due to several physical and environmental constraints. But the pavements are not lasting up to its desired life span due to various reasons which mainly includes improper laying of the paver blocks, insufficient sub base and base course thickness, improper compaction of sub grade etc. Generally, interlocking pavements are expected to have a lifespan of almost 20 years with proper maintenance after the first 15 years. Paver blocks were tested for the specified compressive strength, abrasion test, water absorption, visual inspection requirements as per IS 15658:2006. Bedding sand and filler sand are two major important constituents of interlock pavements. Bedding sand helps in transferring load to the sub base and base course whereas filler sand helps in completing the interlocking nature of the pavement In the present day paver blocks can also be modified to improve its compressive strength, impact strength etc. with the addition of steel slag, rubber pads etc. to prevent failure. There is no standard section design for the interlock pavement to be followed during the pavement construction and also in junctions were bituminous pavement and interlock pavement meet, were impact load will be high in the interlock pavement. Hence a suitable section design as per IRC SP: 63-2004 with the required section thickness and also a design of the pavement section to reduce impact load in bituminous and interlock pavement junction was also put forward.*

***Key Words*: Bedding sand, filler sand, Steel slag, rubber pads**

1. INTRODUCTION

Concrete paver blocks were first introduced in Netherlands in the fifties. Paver blocks became scarce due to post World War II constructions which lead to the development of concrete paver blocks. These blocks were rectangular and had the same size as the bricks. During the past five decades, the block shape has steadily evolved from non-interlocking to partially interlocking to fully interlocking shapes. The pavements in which non-interlocking blocks are used are designated as "Concrete block pavements" (CBP) or non-interlocking CBP and those in which partially or fully interlocking blocks are used are designated as 'interlocking concrete block pavements' (ICBP).

The strength and pleasing surfaces have made paver blocks attractive for parking areas, pedestrian walks, traffic intersections, container yards and roads. Interlocking paver blocks are installed over a compacted stone sub base and leveling bed of sand. Stress cracking and degradation of the surface is minimized because the numerous joints act as the means for load transfer. If mechanical methods of pavement construction are used, then the construction period can be reduced.

This paper focuses on studying the various types of failure and the reasons for failure of interlocking pavements. It will also give an idea about the conditions and design to be followed for proper usage of the pavement without failure during construction of the pavement.

2. USUAL MODES OF FAILURE

Interlock pavements fail due to several reasons. Mostly failure may occur due to improper compaction of base, not providing suitable thickness for base or sub-base course, improper filling of filler sand in between the gaps etc. Drainage and cross slope is also an important factor regarding the serviceability of the interlock pavement. If proper drainage is not provided water will get puddled over the pavement and the sub surface layers will get washed off, hence cross slope of 3% must be provided surface water to be drained of. We visited several interlock pavement sites were failure is severe. Following are some of the usual modes of failure which we found in the visited pavement sites

2.1 Paver are uneven and sitting at different heights

Fig-1: Pavers uneven and sitting at different heights

Most often when we find the pavers that are uneven, it's because the base they have been installed on is not deep enough or not of an even thickness. If the existing project site has clay soils, that means they will hold a lot more water than soils that are more sandy

More water in the soil means that when the ground freezes, it will expand more and push the pavers up. When the ground thaws out again, the pavers aren't always able to go back to the way they were, especially if sand or stone has moved under when they were raised and out of line

2.2 Water puddling on interlock pavement

Fig -2: Water puddling on pavers

There could be 3 things that happened here. If water is puddling, the base may not have been installed at the proper pitch and may have had a slight low spot or the base was not compacted enough, and it has settled over time or the bedding sand layer might have got washed off due to improper drainage.

2.3 The border pavers look like they're falling off

Fig-3: Border pavers are falling off

This mode of failure of occurs when there is no proper edge restraints provided to hold the pavement tightly together or if there is any leak in the underground pipe drains provided in that area, the bedding sand and base course will get washed off and the pavers will fall off.

2.4 Pavers are uneven and tipping

Fig -4 : Individual pavers separating

This occurs when filler sand is not swept in between all the joints of paver blocks. Filler sand is very important in completing the interlocking pattern of the pavement and also for load transfer throughout the pavement. Heavy rain can wash off the filler sand in between the paver blocks. Filler sand helps in holding the pavement together.

3. ANALYSIS OF PAVER BLOCKS

M50 grade paver block samples of 100mm thickness was collected and several tests including compressive strength test, abrasion test, visual inspection and water absorption tests were conducted and the following test results were obtained. All these tests were conducted as per IS 15658: 2006

3.1 Compressive strength

The code specifies individual paver block 28 days compressive strength shall not be less than 85% of specified strength. Most of the compressive strength values were less than 85%of the specified compressive strength. Only 2 samples showed positive results. The following results were obtained.

Table -1: Compressive strength

Compressive strength			
Sample	Load (Tonne)	Area (m^2)	Compressive strength (N/mm^2)
1.	70	0.0318	27.197
2	53	0.0318	20.59
3.	92	0.0318	35.74
4.	110	0..0318	42.78
5.	120	0.0318	46.62

3.2 Abrasion test

The abrasion values of individual test samples were found to be less than 2mm which is the specified limit as per IS15658:2006 code specifications. The following values were obtained.

Table -2: Abrasion test

Abrasion test				
Sample	C1(mm)	C2(mm)	C3(mm)	C4(mm)
1.	22.5	23.42	22.65	23.16
	20.33	21.61	20.77	21.25
Avg=1.81mm	1.92	1.81	1.68	1.91
2.	23.12	24.16	24.10	23.65
	21.22	22.36	22.38	21.81
Avg=1.82mm	1.90	1.80	1.72	1.84
3.	22.42	22.65	22.84	22.48
	20.69	20.85	20.93	20.72
Avg=1.81mm	1.73	1.82	1.91	1.76
4.	23.62	23.81	23.44	23.58
	20.00	22.13	21.72	21.80
Avg=1.70mm	1.62	1.68	1.72	1.78
5.	22.43	22.46	22.82	22.64
	20.70	20.77	21.01	20.89
Avg=1.75mm	1.73	1.69	1.81	1.75
6.	24.64	24.26	24.35	22.72
	22.85	22.54	22.59	22.90
Avg=1.77mm	1.79	1.72	1.76	1.82

3.3 Water absorption test

As per IS 15658:2006, the water absorption value of the tested samples is less than 7%(individual samples) and the average of the three test samples is 1.366% which is less than 6%.Water absorption values for the tested paver blocks are satisfied as per the code specifications.

Table -3: Water absorption test

Water absorption			
Sample	Dry weight (Kg)	Wet weight (Kg)	Water absorption
1.	7.80	7.89	1.153
2.	7.75	7.85	1.240
3.	7.85	7.93	1.656
		Average	1.366

3.4 Visual inspection

Visual inspection shall be conducted by first examining each paver block from a sample lot for any elimination. The blocks shall then be laid out on a level floor in any desired paving pattern, approximately covering a square area of $1m^2$. Any visual defects of paver blocks, including cracks and flaking, shall be recorded by observing the paved blocks from a distance of approximately 2m from each edge of the paved area. Under visual inspection paver blocks were found to be free from cracks and flaking when laid on a level surface.

4. MODIFICATION OF PAVER BLOCK

Concrete paver blocks are made with concrete basically consisting of cement, fine aggregates, coarse aggregates, water, chemical pigments etc. There is a growing interest to increase the basic properties of concrete by using waste materials as alternative aggregate materials. This type of use of a waste material can solve problem of lack of aggregates in various construction sites and reduce environmental problems related to aggregate mining and waste disposal. Rubber pads and steel furnace slag was incorporated with the concrete block paver to improve its impact strength.
Addition of rubber pads will improve the impact strength of the concrete paver block. Rubber pads are placed on the lower side of the paver block mould during casting. Steel furnace slag is added in small percentages as a replacement of filler sand for improving the compressive strength, flexural strength etc. of the paver block.

Fig 5: rubber pad

Fig 6 : Casted paver block

Steel slag is a byproduct, mainly produced in iron and steel manufacturing industries. Compressive strength test were conducted on steel slag reinforced paver blocks in accordance with IS 15658: 2006. Steel slag was added in small percentages replacing fine aggregates.

Both 25% and 50 % steel slag additions showed increase in compressive strength but a greater increase in compressive strength was shown in 25% addition of steel slag. Much more increase in compressive strength will be obtained if the blocks were tested after 28 days of curing.

Table – 4: Compressive strength

Steel slag reinforced compressive strength			
Sample No:	% of steel slag replacing fine aggregates	Compressive strength after 7 days of curing (N/mm^2)	Average compressive strength
1.	0%	41.66	42.91
2.	0%	43.18	
3.	0%	43.90	
4.	25%	47.27	48.02
5.	25%	46.42	
6.	25%	50.39	
7.	50%	42.68	44.23
8.	50%	45.22	
9.	50%	44.81	

5. PAVEMENT SECTION DESIGN

Most of the interlock pavements are laid as per conventional ways or practices. This is also a reason for the failure of pavement. If the required thickness of bedding sand, base course, sub-base course etc. are not provided as per IRC SP: 63-2004 the section will fail. A suitable section design is put forward as per IRC SP: 63-2004.

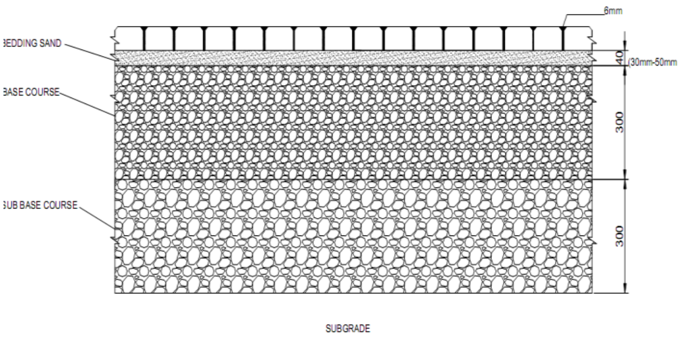

Fig 7: Pavement section

In bituminous and interlock pavement junctions, the impact load acting on the interlock pavement will be high and hence failure will occur at the junctions. Conventionally these junctions are concreted or plastered with cement slurry but that won't help in taking up the impact load acting on the interlock pavement. Hence rubber membranes' or rubber pad can be introduced at the junctions so as to take up the impact load and transfer it to the underlying layers. Rubber pads or membranes' can also be provided in the bedding sand layer, for a small length below the paver block. Suitable section designs at junctions, including rubber pads is given below.

In figure 8 the rubber pad is provided at the junction between bituminous pavement and interlock pavement. It is provided up to a certain depth downwards to transfer the impact load downwards in the pavement. This can also act as a speed breaker if required by increasing the height.
In figure 9 the rubber pad is provided below the paver block, that is within the bedding sand layer up to a certain length and the junction is plastered with cement.

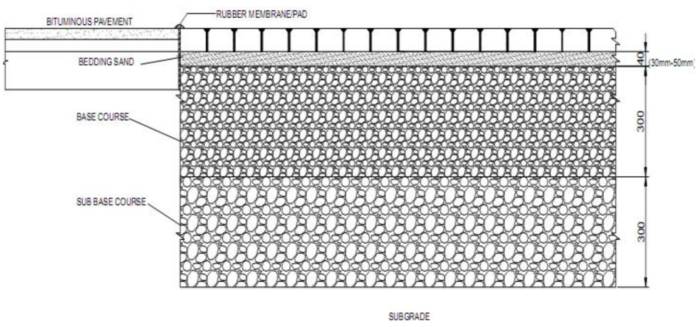

Fig 8: Pavement section with rubber pad

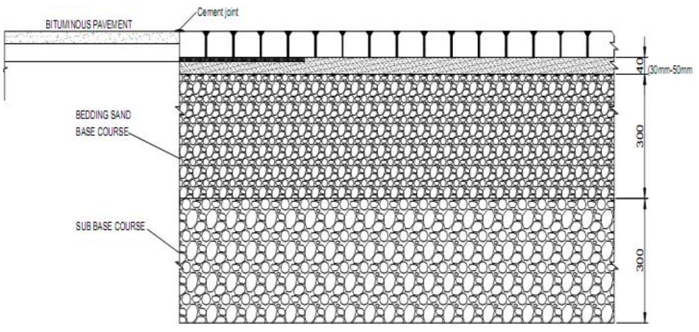

Fig 9: Pavement section with rubber pad

6. CONCLUSIONS

Interlocking concrete block pavements are widely used in the present generation and will also be used in the coming generations due to its fast mode of construction and less cost compared to that of other pavements. But it is not laid in a long span, mostly interlock pavements are laid in small pocket roads, road junctions etc. Failure of the pavement is mainly due to the following reasons

- Inadequate thickness of bedding sand, base course, sub-base course layer etc.
- Improper gap filling between the paver blocks
- Lack of proper compaction
- Lack of proper drainage and cross slope
- Nature of sub grade, for example if the sub grade has a clayey texture then it is not suitable for the interlock pavement to be laid
- Wheel load of heavy vehicles with 2 or more axles

But pavement failure problems can be solved up to a great extent if proper design methods are followed; most of the contractors or engineers are not following a proper code design for interlocking pavements.

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