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A study on the strength properties of paver blocks made from unconventional materials

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ABSTRACT: Interlocking Concrete Block Pavement (ICBP) technology has been introduced in India in construction, a decade ago, for specific requirement namely footpaths and parking areas etc. Now ICBP is being adopted extensively in different uses where the conventional construction of pavement using hot bituminous mix or cement concrete technology is not feasible or desirable. In this investigation, various properties such as compressive strength, split tensile strength, bending strength and water absorption of paver blocks consisting of crushed granite, unconventional materials such as kadapa and broken paver for various percentage replacements of coarse aggregate are studied as per IS 15658:2006.

Key words: IS 15658:2006, ICBP, kadapa, broken paver aggregate.

1. INTRODUCTION

Interlocking Concrete Block Pavement (ICBP) has been extensively used in many countries for quite some time as a specialized problem-solving technique for providing pavement in areas where conventional types of construction are less durable due to many operational and environmental constraints. ICBP technology has been introduced in India in construction, a decade ago, for specific requirement namely footpaths, parking areas etc. but now being adopted extensively in different uses where the conventional construction of pavement using bituminous mix or cement concrete technology is not feasible or desirable.

Concrete paver blocks were first introduced in Holland in the fifties as replacement of paver bricks which had become scarce due to the post-war building construction boom. These blocks were rectangular in shape and had more or less 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 to multiply interlocking shapes. Consequently, the pavements in which non-interlocking blocks are used are designated as Concrete Block Pavement (CBP) or non-interlocking CBP, and those in which partially, fully or multiply interlocking blocks are used are designated as 'Interlocking Concrete Block Pavement (ICBP).

CBP/ICBP consists of a surface layer of small-element, solid un-reinforced pre-cast concrete paver blocks laid on a thin, compacted bedding material which is constructed over a properly profiled base course and is bounded by edge restraints/kerb stones. The block joints are filled using suitable fine material. A properly designed and constructed CBP/ICBP gives excellent performance when applied at locations where conventional systems have lower service life due to a number of geological, traffic, environmental and operational constraints. Many number of such applications for light, medium, heavy and very heavy traffic conditions are currently in practice around the world.

Several researchers have studied the use of recycled aggregates in concrete pavers [6-15]. Poon and Chan (2007) have studied recycled concrete aggregates that are contaminated by materials (tiles, clay bricks, glass, wood) commonly found in the construction and demolition waste and observed that it is feasible to allow a higher level of contamination in the recycled concrete aggregates for making the concrete products. Poon and Lam (2008) studied the effects of aggregate-to-cement (A/C) ratios and types of aggregates (natural crushed aggregate (NCA), recycled crushed aggregate (RCA) and recycled crushed glass (RCG)) on the properties of pre-cast concrete blocks. It was found that the compressive strength of the paving blocks decreased as the A/C ratio increased. The results showed that the strength was directly proportional to the crushing strength of the aggregates (i.e., 10% fines value). Moreover, the water absorption of the blocks had a good correlation with the water absorption ability of the aggregate particles. Jankovic et.al. (2012) used recycled crushed bricks as aggregate in the production of concrete elements for the pedestrian zone. They observed that concrete produced from recycled brick aggregate was of less density and strength and of increased absorption. They concluded that replacing up to a 32.5% of natural aggregate with crushed brick aggregate produces concrete blocks, and up to 65% of it produces concrete paving flags which meet the requirements of European standards.

Erdem and Blankson (2013) investigated the feasibility of incorporating 100% recycled aggregates of waste precast concrete and waste asphalt planning as replacements for virgin aggregates in structural concrete to determine the mechanical and environmental performance. Ground granulated blast furnace slag (GGBS) was used as a mineral addition. The test results showed that it is possible to obtain satisfactory performance for strength characteristics of concrete containing recycled aggregates, if these aggregates are sourced from old precast concrete. However, from the perspective of the mechanical properties, the test results indicated that concrete with RAP aggregate cannot be used for structural applications. In terms of leaching, the results also showed that the environmental behaviour of the recycled aggregate concrete is similar to that of the natural aggregate concrete.

1.1 APPLICATION OF ICBP TECHNOLOGY

1. Non-traffic Areas: Building Premises, Footpaths, Malls, Pedestrian Plaza, Landscapes, Monuments Premises, Premises, Public Gardens/Parks, Shopping Complexes, Bus Terminus Parking areas and Railway Platform, etc.

2. Light Traffic: Car Parks, Office Driveway, Housing Colony Roads, Office/Commercial Complexes, Rural Roads, Residential Colony Roads, Farm Houses, etc.

3. Medium Traffic: Boulevard, City Streets, Small Market Roads, Intersections/Rotaries on Low Volume Roads, Utility Cuts on Arteries, Service Stations, etc.

4. Heavy and Very Heavy Traffic: Container/Bus Terminals, Ports/Dock Yards, Mining Areas, Roads in Industrial Complexes, Heavy-Duty Roads on Expansive Soils, Bulk Cargo Handling Areas, Factory Floors and Pavements, Airport Pavement, etc.

2. EXPERIMENTAL INVESTIGATION

2.1 Materials

Ordinary portland cement of 43 grade conforming to IS: 8112 (1989) with a 28-day compressive strength of 51 N/mm^2 is used. Properties of cement are presented in Table 1. The fine aggregate river sand confirms to grading zone II as per IS: 383-1970. Locally available broken granite is used as coarse aggregates. Its specific gravity is 2.62. The coarse aggregates used in this study are crushed granite, kadapa and old paver block aggregate. The specific gravity of granite, broken paver and kadapa are 2.58, 2.44 and 2.60 respectively. Two fractions were used, the first fraction is aggregate passing through 20mm and retained on 12.5mm and the second fraction is passing through 12.5mm and retained on 10mmhe. Portable water free from injurious salts is used for mixing and curing.

Table 1: Properties of cement and recommendations for 43 grade cement

Sl. No.	Properties	Test Results	IS 8112- 1989 Requirements
1	Standard Consistency, %	30.50%	No standard value
2	**Setting time, Minutes**		
	Initial setting time	135	Not less than 30
	Final setting time	225	Not greater than 600
3	Specific gravity	3.15	
4	**Compressive Strength, MPa**		
	3 days	28.39	23
	7 days	40.38	33

	28 days	51.17	43

2.2 Mix proportioning:
In this study, 1:1.5:3 mix proportion is considered. Fixing the w/c ratio at 0.5, the natural coarse aggregate is replaced by 50% and 100% broken paver aggregate and kadapa on weight basis.

2.3 Testing
The number of blocks tested for each batch is given in Table 4.

Table 2: Samples tested as per IS: 15658:2006

Property	Reference Clause No.	Testing method	Number of paver blocks for each test
Water absorption	6.2.4	Annex C	3
Compressive strength	6.2.5	Annex D	8
Tensile splitting strength	6.3.1	Annex E	8
Flexural strength	6.3.2	Annex F	8

3. RESULTS AND DISCUSSION
3.1 Water absorption
From the Table 3, water absorption of the paver blocks containing conventional granite aggregate, kadapa aggregate is well within 7%, the maximum value specified by the code. The water absorption of paver block containing crushed paver as coarse aggregate is significantly higher and is due to high water absorption of the paver aggregate. Similar observations were made by Erdem and Blankson (2013).

Table 3: Variation of water absorption for paver blocks containing different types of coarse aggregate at 7 days (mix: 1:1.5:3, w/c=0.5)

Type of aggregate	Water absorption at 7 days, %
100% Natural aggregate	6.45
100% Broken paver aggregate	8.80
100% Kadapa aggregate	5.01
50% Broken paver + 50% Natural aggregate	7.20
50% Kadapa+ 50% Natural aggregate	4.42

3.2 STRENGTH
From Table 4, Compressive strength of paver block containing broken paver as aggregate is significantly less compared to paver block containing granite aggregate. Such paver blocks can be used for pedestrian and light traffic applications such as pedestrian plazas, shopping complexes ramps, car parks, housing colonies, residential roads etc. The same trend of observation is noticed for splitting and bending strength as seen in Tables 5 and 6.

When waste kadapa is used as a recycled aggregate, all strengths namely compression, bending and splitting are in par with that of paver blocks containing granite aggregate as observed in Tables 4-6. This is due to the fact that the kadapa stone is equally strong as that of granite aggregate in terms of impact and crushing strength. There exists a good correlation between compressive, bending and splitting strengths for paver blocks, in the same way as it exists in conventional concrete. This trend agrees with results reported by Poon and Lam (2008).

Table 4: Variation of Compressive Strength at 7 days for paver blocks containing different types of coarse aggregate (mix: 1:1.5:3, w/c=0.5)

Type of aggregate	Compressive strength, N/mm^2
100% Natural aggregate	43.38
100% Broken paver aggregate	30.10
100% Kadapa aggregate	37.73
50% Broken paver + 50% Natural aggregate	32.00
50% Kadapa+ 50% Natural aggregate	44.62

Table 5: Variation of splitting strength at 7 days for paver blocks containing different types of coarse aggregate (mix: 1:1.5:3, w/c=0.5)

Type of aggregate	Splitting strength, N/mm^2
100% Natural aggregate	2.82
100% Broken paver aggregate	2.35
100% Kadapa aggregate	2.38
50% Broken paver + 50% Natural aggregate	2.12
50% Kadapa+ 50% Natural aggregate	3.44

Table 6: Variation of bending strength at 7 days for paver blocks containing different types of coarse aggregate (mix: 1:1.5:3, w/c=0.5)

Type of aggregate	Bending strength, N/mm^2
100% Natural aggregate	5.66
100% Broken paver aggregate	6.42
100% Kadapa aggregate	7.25
50% Broken paver + 50% Natural aggregate	3.35
50% Kadapa+ 50% Natural aggregate	4.75

4. CONCLUSION

Following four important conclusions are arrived based on the discussion of the test results.

- Broken paver aggregate is not suitable in making paver blocks as the absorption is more than 7%. However, 50% replacement of paver aggregate with natural aggregate may be used as the absorption is very close to the acceptable limits.
- Kadapa aggregates are better than granite aggregate in terms of water absorption limits.
- Kadapa as paver aggregate is most suitable for paver blocks as it gives better strength like natural aggregate.

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