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Utilization of Quarry Dust in Cement Concrete Paver Blocks for Rural Roads

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Abstract— *Solid unreinforced pre-cast cement concrete paver blocks is a versatile, aesthetically attractive, functional, cost effective and requires little or no maintenance if correctly manufactured and laid. Paver blocks can be used for different traffic categories i.e. Non-traffic, Light-traffic, Medium-traffic, Heavy-traffic and Very heavy traffic. Concrete block paving is versatile, aesthetically attractive, functional, and cost effective and requires little or no maintenance if correctly manufactured and laid. Most concrete block paving constructed in South Africa has Performed satisfactorily but there are two main areas of concern: occasional failure due to excessive surface wear, and variability in the strength of blocks. Paving block is a very common and popular method of hard landscaping that is suitable for various applications including: driveways, paths, patios, public utility areas, garage, forecourts and roads etc. IS 15658: 2006 says that paver blocks can used in rural roads when it is casted by M 35 grade of concrete and 60 mm thick. In this project 60 mm thick and paver blocks of M35 concrete grade is casted. quarry fines which is waste product of stone industry and generated as a waste during the process of cutting and crushing of stones are going to use as fine aggregate in this project. Fine aggregate is going to replace by quarry dust (which is retained on 4.75 mm IS sieve) upto 100% at an interval of 10% and test like compressive strength along with flexural strength is performed on paver blocks. Workability of the concrete is also checked.*

I. LITERATURE REVIEW

In this chapter literature review and previous studies done on paver blocks, rural roads and quarry fines is shown. Previous work along with author and year of research with title is given below.

II. RESEARCH BACKGROUND

"Stone crusher dust as a fine aggregate in Concrete for paving blocks" Replacement fine aggregate by crusher dust up to 50% by weight has a negligible effect on the reduction of any physical and mechanical properties like compressive strength, flexural strength, split tensile strength etc. Water absorption is well below the limit as per Indian codes. Durability test shows no variation for different replacements of crusher dust. There is a saving of 56% of money if sand is replaced by crusher dust. The percentage of saving was less but highly beneficial for mass production of paving blocks.

"A study of utilization aspect of quarry dust in Indian context" Natural river sand, if replaced by hundred percent Quarry Rock Dust from quarries, maysometimes give equal or better than the reference concrete made with Natural Sand, interms of compressive and flexural strength studies The strength of Quarry Rock Dust concrete is comparatively 10-12 percent more than that of a similar mix of Conventional Concrete. The Durability of Quarry Rock Dust concrete under sulphate and acid action is higher inferior to the Conventional. Permeability Test results clearly demonstrate that the permeability of Quarry Rock Dust concrete is less compared to that of conventional concrete.

"Strength and durability properties of concrete containing quarry rock dust as fine aggregate" Natural river sand, if replaced by hundred percent Quarry Rock Dust from quarries, may sometimes give equal or better than the reference concrete made with Natural Sand, in terms of compressive and flexural strength studies. Also the result of this investigation shows that drying shrinkage strains of Quarry Rock Dust concrete are quite large to the shrinkage strain of Conventional Concrete.

"An Experimental Study on Usage of Quarry Rock Dust as Partial Replacement for Sand in Concrete" The compressive strength of cubes with 28 days curing of controlled specimen Q0 is observed as 23.25 N/mm2. For 20% quarry dust replaced specimen i.e., Q20, the strength has been increased to 19.18% and for 40% quarry dust replaced specimen i.e., Q40, the strength has been increased to 35.26% but for 60% quarry dust replaced specimen i.e., Q60, the strength has been increased only upto 12.73%.

III. INTRODUCTION

Many of the poor communities are isolated by distance, bad road conditions, lack of or broken bridges and inadequate transport. These conditions make it difficult for people to get their goods to market and themselves to place of work, to handle health emergencies, to send children to school, and to obtain public services. A community without roads does not have a way out. If we get the road, we would get everything else, community centre, employment, post-office, telephone etc.

Rural Road connectivity is a key component of rural development, since it promotes access to economic and social services, thereby generating increased agricultural productivity, non-agriculture employment as well as non-agricultural productivity, which in turn expands rural growth opportunities and real income through which poverty can be reduced. A study carried out by the International Food Policy Research Institute on linkages between government expenditure and poverty in rural India has revealed that an investment of Rs 1 crore in roads lifts 1650 poor persons above the poverty line. Public investment on roads impacts rural poverty through its effect on improved agricultural productivity, higher non-farm employment opportunities and increased rural wages. Improvement in agricultural productivity not only reduces rural poverty directly by increasing income of poor households, it also causes decline in

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poverty indirectly by raising agricultural wages and lowering food prices (since poor households are net buyers of foodgrains). Similarly, increased non-farm employment and higher rural wages also enhance incomes of the rural poor and consequently, reduce rural poverty.

A. Application of Paver Block

Concrete pavers are a versatile paving material, which due to the availability of many shapes, sizes and colours, has endless streetscape design possibilities. The use of concrete block paving can be divided into the following categories:

Roads

- Main roads
- Residential roads
- Urban renewal
- Intersections
- Toll plazas
- Pedestrian crossings
- Taxi ranks
- Steep slopes
- Pavements (sidewalks)

The change in texture of the road surface at intersections produces an audible change in road noise, thereby alerting drivers to the fact that they are approaching the intersection.

Commercial Projects

- Car parks
- Shopping centers and malls
- Parks and recreation centers
- Golf courses and country clubs
- Zoos
- Office parks
- Service stations
- Bus termini
- Indoor areas
- Places of worshiP.

Industrial Areas

- Factories and warehouses
- Container depots
- Military applications
- Mines
- Wastewater reduction works
- Quarries
- Airports and harbors

Domestic paving

- Pool surrounds
- Driveways
- Patios
- Townhouses and cluster homes

Concrete block paving provides functional yet very attractive pool surrounds. Driveway paved with concrete block paving will enhance the value of property. Concrete block paving is both attractive and functional. Concrete block paving blends in with the landscape and increases the attractiveness and value of townhouses and cluster homes.

Specialized Applications

- Cladding vertical surfaces
- Storm water channels
- Embankment protection under freeways
- Roof decks

B. Obligatory Requirements

1. Visual requirements

Visual inspection of quality of paver blocks shall be carried out in natural daylight, prior to the test for other properties. The inspection shall be conducted by the purchaser and the manufacturer jointly at a location, agreed to between them, normally at the site or factory.

- *Dimensions and Tolerances*

The recommended dimensions and tolerances for paver blocks are measured by steel calipers and steel ruler. Specified tolerance as IS 15658: 2006 is given below in table.

TABLE 1. Recommended Dimension and tolerance for paver blocks

S.No.	Dimensions	Recommended values	Tolerance limit	
			Thickness <100mm	Thickness >100mm
1.	Width, W	To be specified by manufacturer	± 2mm	± 3mm
2.	Length, L	To be specified by manufacturer	± 2mm	± 3mm
3.	Thickness, T	50 to 120 mm	± 3mm	± 4mm
4.	Aspect ratio (L/T)	Maximum 4.0	+ 0.2	+ 0.2
5.	Arris/Chamfer	Minimum: 5mm Maximum: 7mm	± 1mm	± 1mm
6.	Thickness of wearing layer	Minimum: 6mm	+2mm	+ 2mm
7.	Plan area, Ast	Maximum: $0.03m^2$	+ $0.001m^2$	+ $0.001m^2$
8.	Wearing face area, Asw	Minimum 75% of plan area	- 1%	- 1%
9.	Squareness	Nil	± 2mm	± 3mm

- *Water Absorption*

The water absorption, being the average of the three units, and water absorption of paver block shall not be more than 6% by mass and in individual samples, the water absorption should restricted to 7 percent.

- *Compressive Strength*

Compressive strength of paver blocks shall be specified in terms of 28 days compressive strength. The average 28 days compressive strength of paver blocks shall meet the specific requirement. Individual paver block strength shall not be less than 85% of the specified strength.

The specified average 28 days compressive strength of different grades of paver blocks are grade of the concrete >= Fck + 0825 * standard deviation (round of nearest 0.5 N/mm^2)

- *Abrasion Resistance*

Abrasion resistance is a property which allows a material to resist wear. Materials which are abrasion resistant are useful for situations in which mechanical wearing and damage can occur, including delicate applications such as the construction of space shuttle components. Numerous companies manufacture abrasion resistant products for a variety of applications, including products which can be custom fabricated to meet the needs of specific users. The Abrasion resistance of paver blocks may be specified in the to the test results, which should be complied with by the manufacturer.

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A. Tensile Splitting Strength

The tensile strength is one of the basic and important properties of the concrete. The concrete is not usually expected to resist the direct tension because of its low tensile strength and brittle nature. However, the determination of tensile strength of concrete is necessary to determine the load at which the concrete members may crack. The cracking is a form of tension failure. Apart from the flexure test the other methods to determine the tensile strength of concrete can be broadly classified as (a) direct methods, and (b) indirect methods. The direct method suffers from a number of difficulties related to holding the specimen properly in the testing machine without introducing stress concentration, and to the application of uniaxial tensile load. Which is free from eccentricity to the specimen. As the concrete is weak in tension even a small eccentricity of load will induce combined bending and axial force condition and the concrete fails at the apparent tensile stress other than the tensile strength. As there are many difficulties associated with the direct tension test, a number of indirect methods have been developed to determine the tensile strength. In these tests in general a compressive force is applied to a concrete specimen in such a way that the specimen fails due to tensile stresses developed in the specimen. The tensile stress at which the failure occurs is termed the tensile strength of concrete.

- The test is simple to perform and gives more uniform results than that given by other tests.
- The strength determined is closer to the actual tensile strength of concrete than the modulus of rupture value.
- The same molds and testing machine can be used for compression and tension tests.

B. Flexural Strength/Breaking Load

Maximum fiber stress developed in a specimen just before it cracks or breaks in a flexure test. Flexural yield strength is reported instead of flexural strength for materials that do not crack in the flexure test. An alternate term is modulus of rupture. The Flexural strength/ Breaking Load of paver blocks is done when it is required by purchaser and its test value should be specified by the purchaser.

C. Freeze-Thaw Durability

When water freezes, it expands about 9 percent. As the water in moist concrete freezes it produces pressure in the pores of the concrete. If the pressure developed exceeds the tensile strength of the concrete, the cavity will dilate and rupture. The accumulative effect of successive freeze-thaw cycles and disruption of paste and aggregate can eventually cause expansion and cracking, scaling, and crumbling of the concrete. When required for application in freez and thaw environment, the purchaser may specify limits to the test results, which should be completed with bt the manufacturer.

D. Colour and Texture

Colour and texture is given to paver block to make it visible and also for skid resistance or to provide friction. When required, the colour and texture of paver blocks should be manually agreed to between the purchaser and the manufacturer.

Grade Destination of Paver and Design of Concrete Block Pavement

Recommended frades of paver blocks to be used for construction of pavements having different traffic categories are given in table below. Since zero slump concrete is used in production of paver blocks, the quality of blocks produced will depend upon various parameters like the capacity of compaction and vibration of machine, grade of cement used, water content, quality of aggregate used, their gradation and mix design adopted, additives used, handling equipment employed, curing methods adopted, level of supervision, workmanship and quality control achieved etc.

TABLE II. Grades of paver blocks for traffic categories.

S. No.	Grade Designation of Paver Blocks	Specified Compressive Strength of Paver Blocks at 28 Days N/mm^2	Traffic Category	Recommended Minimum Paver Block Thickness	Traffic Examples of Application
1.	M-30	30	Non-Traffic	50	Building premises, monuments premises, landscapes, public garden/parks, domestic drivers, paths and patios, embankment slopes, sand stabilization area etc
2.	M-35	35	Light-Traffic	60	Pedestrian plazas, shopping complex ramps, car parks, office driveways, housing colonies, office complexes, rural roads with low volume traffic, farm houses, beach sites, tourist resorts local authority footways, residential roads etc.
3.	M-40	40	Medium-Traffic	80	City Streets, small and medium market roads, low volume roads, utility cuts on arterial roads etc
4.	M-50	50	Heavy-Traffic	100	Bus terminal, industrial complexes, mandi houses, roads on expansive solis, factory floor, service stations, industrial pavements etc
5.	M-55	55	Very Heavy-Traffic	120	Container terminal, ports, docks yards, mine access roads, bulk cargo handling areas, airport pavement etc.

NOTE

- Non-traffic areas are defined as areas where no vehicular traffic occurs.
- Light-Traffic is defined as a daily traffic up to 150 commercial vehicles exceeding 30 KN laden weight, or an equivalent up to 0.5 million standard axels (MSA) for a design life of 20 years (A standard axel is defined as a single axle load of 81.6 KN)
- Medium traffic is defined as a daily traffic of 150 – 450 commercial vehicles exceeding 30 KN laden weight, or an equivalent up to 0.5 – 2.0 MSA for a design life of 20 years.

- Heavy traffic is defined as a daily traffic of 450 – 1500 commercial vehicles exceeding 30 KN laden weight, or an equivalent of 2.0 to 5.0 MSA for design life of 20 years.
- Very heavy traffic is defined as a daily traffic of more than 1500 commercial vehicles exceeding 30 KN laden weight, or an equivalent of more than 5.0 MSA for design life of 20 years.

Material Specification

Cement

Cement used shall be any of the following:

- Ordinary Portland cement of grade 33 conforming to IS 269

Physical Requirements

- Fineness

When tested for fineness by Blaine's air permeability method as described in IS 4031 (Part 2) :1988. The specific surface of cement shall not be less than 225 m'/kg.

- Soundness

When tested by 'Le Chatelier' method and autoclave test described in IS 4031 (Part 3) : 1988, unaerated cement shall not have an expansion of more than 10 mm and 0'8 percent, respectively.

- Setting Time

The setting time of the cements, when tested by the Vicat apparatus method described in IS 4931 (Part 5) : 1988 shall conform to the following requirements:

- Initial setting time in minutes, not less than 30; and
- Final setting time in minutes, not more than 600.
- Compressive Strength

The average compressive strength of at least three mortar cubes (area of face 50 cm^2) composed of one part of cement, three parts of standard sand (conforming to IS 650 : 1966) by mass and (P/4 + 3.0) percent (of combined mass of cement plus sand) wafer and prepared, stored and tested in the manner described in IS 4031 (Part 6): 1988 shall be as follows:

- 72 ± 1 hour: not less than 16 MPa,
- 168 ± 2 hours: not less than 22 MPa, and
- 672&4 hours: not less than 33 MPa.

Ordinary Portland Cement of grade 43 conforming IS 8112:

Physical Requirements

- Fineness

When tested for fineness by Blaine's air permeability method as described in IS 4031 (Part 2) : 1988, the specific surface of cement shall not be less than 225 m^3/kg.

- Soundness

When tested by the 'Le-Chatelier' method and autoclave test described in IS 4031 (Part 3) :1988, unaerated cement shall. not have an expansion of more than 10 mm and 0.8 percent respectively.

- Setting Time

The setting time of cement, when tested by the Vicat apparatus method described in- IS 4031 (Part. 5), : 1988 shall conform to the following requirements:

- Initial. setting time in minutes - not less than 30
- Final setting time in minutes – not less than 600
- Compressive Strength

The average compressive strength of at least three mortar cubes (area of face 50 cm^2) composed of one part of cement, three parts of standard sand (conforming to IS 650 : 1966) by mass and P/4 + 3.0 percent (of combined mass of cement plus sand) water, and prepared, stored and tested in the manner described in IS 4031 (Part 6) : 1988, shall be as follows:

- 72 ± 1 hour: not less than 23 MPa,
- 168 ± 2 hours: not less than 33 MPa, and
- 672&4 hours: not less than 43 MPa.

Ordinary Portland Cement of grade 53 conforming IS 12269 : 1987

Physical Requirements

- Fineness

When tested for fineness by Blaine's air permeability method as described in IS : 403 l -19687, the specific surface 01 cement shall not be less than 225 m^3/kg.

- Soundness

when tested by the 'Le Chatelier' method G. ,1 autoclave test described in IS : 4031-19687, unaerated cement shall not have an expansion of more than 10 mm and 0.8 percent, respectively.

- Setting Time

The setting time of cement, when tested by the Vicat apparatus method described in IS : 4031-1968* shall conform to the following requirements:

- Initial setting time in minutes – not less than 30, and
- Final setting time in minutes – not more than 600.
- Compressive Strength

The average compressive strength of at least three mortar cubes (area of face **50** cm^2) composed of one part of cement, three parts of standard sand (conforming to IS : 650-19661_) by mass and P/4 + 3.0 percent (of combined mass of cement plus sand) water, and prepared, stored and tested in the manner described in IS : 4031-19637, shall be as follows:

- 72 ± 1 hour: not less than 27 MPa,
- 168 ± 2 hours: not less than 37 MPa, and
- 672&4 hours: not less than 53 MPa.

Aggregates

A. Coarse Aggregates

The aggregates which remained on 4.75mm IS Sieve is called coarse aggregates, coarse aggregate is uncrushed gravel or stone which results from the natural disintegration of rocks, crushed gravel or stone when it results from crushing of gravel or hard stone. Coarse aggregates which is used in paver blocks is confirmed by IS 383. As far as possible crushed/ semi crushed aggregates shall be used. For ensuring adequate durability, the aggregate used for production of blocks shall be sound and free of soft or honey combed particles.

The nominal size of coarse aggregates used in production of paver blocks shall be 12 mm.

- Fine Aggregates

Aggregate which passed from 4.75 mm sieve and contains only so much coarser material as permitted, fine aggregate is natural sand which is resulting from the natural disintegration of rock and which has been deposited by streams or glacial agencies, it is also crushed stone sand which is produced by crushing hard stone, it is also crushed gravel sand which produced by crushing natural gravel.

Admixture

Admixtures when used shall conform to IS 9103. Previous experience with and data on such materials should be considered in relation to the specified standard of mechanic mechanization, supervision and workmanship in production of blocks. They may be added for specific requirement without affecting other quality parameter.

Pigments

Synthetic or natural pigments may be used in concrete mix to obtain paver blocks with desired shades of colours. The pigment used should result in durable colours of paver blocks. It shall not contain matters detrimental to concrete. Pigments, either singly or in combination, conforming some Indian standard according to their colour, the standard which may be preferably be used id given below

TABLE III. Recommended IS codes for use of pigments.

Pigments	Relevant Indian Standard
Black or RED or Brown Pigment	IS 44
Green Pigment	IS 54
Blue Pigment	IS 55 or IS 56
White Pigment	IS 411
Yellow Pigment	IS 50

These pigments should not contain zinc compounds or organic dyes and lead pigments shall not be used.

Water

Water used in paver blocks shall conform to the requirements specified in IS 456 : 2000. According to IS 456 water used for mixing and curing shall be clean and free from injurious amount of oils, acids, alkalis, salts, sugar, organic materials or other substances that may be deleterious to concrete or steel. Portable water is generally considered satisfactory for mixing concrete. The water which is used in mixing and curing should have ph value less than 6. Sea water is not recommended for curing and mixing because of presence of harmful salts in sea water. Under unavoidable circumstances sea water may be used for mixing or curing.

Installation of Paver Blocks

Priming

The contractor is required to verify the existing WBM driveway surface and ascertain the CBR value. Accordingly the total sub grade thickness required for achieving the desired CBR value shall be advised to HPCL within seven days of receipt of call-up. HPCL shall, through regular vendors arrange to carry out such WBM, wherever required. Before taking over the site, the Paver block laying party is required to verify the stabilization of the surface with CBR values. In case, contractor does not advise the CBR value within seven days, HPCL shall carry out WBM as per own design, and contractor shall have no claim later particularly to the quality of WBM or sub-grade.

Bedding Sand Course

The bedding sand shall consist of naturally occurring, clean, well graded sand passing through 4.75mm sieve and suitable to concrete manufacture. The bedding should be from either a single source or blended to achieve the grading. Contractor shall be responsible to ensure that single-sized, gap-graded sands or sands containing an excessive amount of fines or plastic fines are not used. The sand particles should preferably be sharp, not rounded. The sand used for bedding shall be free of any deleterious soluble salts or other contaminants likely to cause efflorescence. The sand shall be of uniform moisture content, which shall be within 4% - 8%, at the time of spreading and shall be protected against rain when stockpiled prior to spreading. Saturated sand shall not be used.

Laying Of Interlocking Paver Block

Paver block shall be laid in pattern as specified under cl. 7 throughout the pavement. Once the laying pattern has been established, it shall continue without interruption over the entire pavement surface. Cutting of blocks, the use of infill concrete or discontinuities in laying pattern is not to be permitted in other than approved locations. Paving units shall be placed on the uncompacted sand bed to the nominated laying pattern; care shall be taken to maintain the specified bond throughout the job. The first row shall be located next to an edge restraint. Paver block shall be placed with the help of spacers to achieve gaps nominally 2 to 3mm wide between adjacent paving joints. No joint shall be less than 2mm nor more than 4mm. However it is mandatory to use 3.0mm wide spacer while laying paver tiles so as to ensure uniform 3.0mm gap between adjacent pavers. Frequent use of string lines shall be used to check alignment. In this regard, the "laying face" shall be checked at least every two metre as the face proceeds. In each row, all full units shall be laid first. Closure units shall be cut and fitted subsequently. Such closure units shall consist of not less than 25% of a full unit.

To fill spaces between 25mm and 50mm wide, concrete having minimum 1:1:2 cement : sand : coarse aggregate mix and a strength of 40 N/mm^2 shall be used. Within such mix the nominal aggregate size shall not exceed one third the smallest dimension of the infill space. For smaller spaces dry packed mortar shall be used.

Initial Compaction

After laying the paver block, they shall be compacted to achieve consolidation of the sand bedding and brought to design levels and profile by not less than two (2) passes of a suitable plate compactor. The compactor shall be a high-frequency, low amplitude mechanical flat plate vibrator having plate area sufficient to cover a minimum of twelve paving units. Prior to compaction all debris shall be removed from the surface. Compaction shall proceed as closely as possible following laying and prior to any traffic. Compaction shall not, however, be attempted within one meter of the lying face. Compaction shall continue until lipping has been eliminated between adjoining units. Joints shall then be filled and Recompacted.

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Joint Filling and Final Compaction

As soon as practical after compaction and in any case prior to the termination of work on that day and prior to the acceptance of any traffic, sand for joint filling shall be spread over the pavement. Joint sand shall pass a 2.36mm (No. 8) sieve and shall be free of soluble salts or contaminants likely to cause efflorescence. The same shall comply with the grading limits. The Contractor shall supply a sample of the jointing sand to be used in the contract prior to delivering any such material to site for incorporation into the works. Certificates of test results issued by a recognized testing laboratory confirming that the sand sample conforms to the requirements of this specification shall be submitted prior to supply of total volume required. The jointing sand shall be broomed to fill the joints. Excess sand shall then be removed from the pavement surface and the jointing sand shall be compacted with not less than one (1) pass of the plate vibrator and joints refilled with sand to full depth. This procedure shall be repeated until all joints are completely filled with sand. No traffic shall be permitted to use the pavement until all joints have been completely filled with sand and compacted. Both the sand and paver block shall be dry when sand is spread and broomed into the joints to prevent premature setting of the sand. The difference in level (lipping) between adjacent units shall not exceed 3mm with not more than 1% in any 3m X 3m area exceeding 2mm. Pavement portions which are deformed beyond above limits after final compaction, shall be taken out and relaid to the satisfaction of the Engineer in chargeS.

Edge Restraint Using Kerb Block

Edge restraints shall be done using the kerb blocks as specified in 3.9.They should be fixed properly to withstand overriding by the anticipated traffic, thermal expansion and to prevent loss of the laying course material from beneath the surface course. The edge restraint should present a vertical face down to the level of the underside of the laying course. The surface course should not be vibrated until the edge restraint, together with any bedding or concrete haunching, has gained sufficient strength. It is essential that edge restraints are adequately secured.

Uniform Interlocking Spaces

The pavers should have uniform interlocking space of 2mm to 3mm to ensure compacted sand filling after vibration on the paver surface.

Skilled Labour

Skilled labour should be employed for laying blocks to ensure line and level of pavers, desired shape of the surface and adequate compaction of the sand in the joints.

- Quarry Fines

Quarrying, and the associated processing operations, inevitably leads to the production of quarry fines. The amount produced depends upon the geology, the rock type quarried, the efficiency of the extraction and processing operation and the local market for quarried products. Quarry fines,defined by BS EN standards, are the inherent fraction of an aggregate passing 0.063 mm (63 microns). Many quarries also refer to their (sub-economic) fine aggregate (finer than 4 mm) as quarry fines (or quarry dust). The term is used here to denote both fine aggregate and quarry fines (material <63 microns). Quarry fines can be considered a mixture of coarse, medium and fine sand material, and silt / clay (silt and clay are often known collectively as ‘filler’).

The taxes on waste disposal and on production of primary aggregate materials have encouraged the use of secondary materials as aggregate, but have depressed the market for quarry fines. Many quarries in the UK have large stockpiles of fines they cannot sell. Also, large demand for high-specification fine aggregate, and aggregate with specific shape characteristics, has resulted in an increase in fines production.

Production of quarry fines

Quarry fines are generated by processes related to blasting, processing, handling and transportation. Particle shape, as well as grading and fines content, are a function not only of the crushing process but also of the mineral composition and texture of the rock. As a rule of thumb, a coarse-grained rock will generate fewer fines than a fine-grained rock. This is because it takes less energy to separate individual mineral particles than it does to crush them. Also, minerals with low abrasion resistance (i.e. softer materials) will breakdown more readily than harder materials and produce more fines.

The amount of fines generated during blasting may be as high as 20%; adapting the blasting process to produce larger broken rock fragments can reduce the generation of blasting-related fines. However, this may lead to an increase in secondary breakage, downstream crushing costs and equipment maintenance costs. If fragmentation is too great, an excess of fines could result. Blasting tends to be optimised according to handling and crusher efficiency criteria rather than fines minimisation.

Most quarry fines are produced during the crushing, milling and screening of quarried rock to produce single-size aggregate (ranging from 20 mm to 6 mm) and other products. Crushing of quarried rock is carried out in stages, with the primary crushing stage typically carried out using jaw crushers or gyratory crushers and subsequent (secondary and tertiary) stages by cone or impact crushers. Fines production increases with an increase in the number of crushing stages. Multiple (three or four) stages are often used to keep the reduction ratio at each stage relatively low. Although, this minimises fines generation at each stage, the cumulative fines production may be higher than a process using fewer stages with higher reduction ratios. Table 1 indicates the fines content generated at each stage of the crushing process. The proportion of fines produced varies with the type of rock and also the type of crusher used. The figures are estimates, largely based on operator experience and gathered during a survey of quarrying operations.

TABLE IV. Quarry fines produced at each crushing stage.

Production Stage	Quarry fines produced by hard rock quarries	
Primary crusher	Igneous Limestone Gritstone	3 – 6% (Jaw) to 10-15% (Gyratory) 6 – 7% (Jaw) to 20% (Impact) 1 – 2% (Jaw) to 15 – 20% (Jaw & Gyratory)
Secondary crusher	Igneous Limestone Gritstone	10 – 23% (Cone) <10% (Cone) to <20% (Impact) 4 – 5% (Jaw & Cone)

Tertiary crusher (& further)	Igneous Limestone Gritstone	5 – 30% (Cone) to 40% (Impact) <20% (Impact) to 40% (Hammer mill) ~15% (Cone) to 40% (Impact)

The type of crusher used also directly controls the amounts of fines produced. It is well known that impact crushing produces more fines than compressive crushing. Impact crushers, such as horizontal and vertical shaft impactors, tend to produce 25 - 30% more fines than compressive crushers, such as jaw crushers and cone crushers. The type of impact applied in a vertical shaft impact crusher also influences the production of fines. Rock-on-rock interaction helps to improve particle shape and reduce crusher wear but leads to increased fines production. Rock-on-metal interaction produces fewer fines while maintaining a cubical product but leads to greater crusher wear.

In the past, quarries produced a range of single-size aggregate products up to 40 mm in size. However, the recent trend has been for highly specified aggregate, typically finer than 20 mm. It is not unusual for material coarser than 10 mm to be stockpiled and recrushed on demand. The production of aggregate with a smaller particle-size has had a dramatic effect on the proportion of fines produced; a 40 mm top size results in 5 to 10% fines, 20 mm top size, 15 to 20% fines and 10 mm top size, 35 to 40% fines.

Advantages and Limitations

CBP does not require curing, and so can be opened for traffic immediately after construction.

Construction of CBP is labor intensive and requires less sophisticated equipment.

- The system provides ready access to underground utilities without damage to pavement.
- Maintenance of CBP is easy and simple and it is not affected by fuel and oil spillage.
- Use of colored blocks facilitates permanent traffic markings.
- CBP is resistant to punching loads and horizontal shear forces caused by maneuvering of heavy vehicles
- Low maintenance cost and a high salvage value ensures low life cycle cost.

However, important limitations of the technique are the following:

- Quality control of blocks at the factory premises is a prerequisite for durable "CBP"
- Any deviations of base course profile will be reflected on the "CBP" surface. Hence extra care needs to be taken to fix the same.

IV. SCOPE OF THE STUDY

Scope of the study is to make rural roads effective and also construction of rural roads becomes easy and economic. The performance of paver blocks pavement depends on mechanical properties of concrete blocks and structural design of the pavement, for a serviceable paver blocks pavement, both factors have to be studied. paver block pavement have a unique ability of transferring loads and stresses over large areas for paving, They also have a good wearing resistance and adequate skid resistance and laying can be done by unskilled labor under proper supervision. Paver block pavement can be used immediately after laying. Maintenance cost of paver blocks roads is less and No thermal expansion and contraction of concrete. Other scope of this study is to enhance the industry understanding of the sustainable utilization of quarry fines, and to identify any gaps in current knowledge. utilization implies the use of quarry fines to their full potential to meet the needs of the present, while at the same time conserving natural resources and finding ways to minimize the environmental impacts associated both with quarry fines production and use.

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