Preparation of Data-Base of Conventional/ Locally Available / Marginal Materials for Construction of Embankment and Pavement Layers

Final Report – August 2016

Sponsored by

National Rural Roads Development Agency, New Delhi

Geotechnical Engineering Division

DISCLAIMER

All the data and technical information furnished in this report are based on the investigations carried out in the field and at laboratories of the CSIR-Central Road Research Institute (CRRI), New Delhi. The responsibility of CRRI is limited to the technical and scientific matters contained in this report. All the procedural/ legal/ operational matters would be responsibility of NRRDA who would be using this report.

ACKNOWLEDGEMENTS

The research work described in this report was carried out in Geotechnical Engineering Division of CSIR-Central Road Research Institute. The project team is immensely grateful to Mr.Rajesh Bhushan, JS (RC) and DG (NRRDA), Dr.I.K.Pateria, Director (Technical), S/Shri Chaman Lal, Director and Basavaraju, Director, and their staff at NRRDA for giving us an opportunity to work on this project and guiding and helping us throughout this study. We are thankful to S/Shri D.P.Gupta, S.C.Sharma and Prof P.K.Sikdar for extremely useful suggestions made during project formulation and during the course of work. We express our gratitude to BRRDA officers and engineers - Dr.B.Rajendra, former Secretary, Rural Works Department, Dr.S.Sidharth, Secretary, Rural Works Department, S/Shri K.N.Prasad, Subhash Chandra, Kumar Rakesh, Y.P.Sharma, Ramashray Sahni, S.P.Srivastava and all their PIU staff, Contractors, NTPC Officials, Prof M.Mandal, STA incharge, Bhagalpur, Dr.A.K.Thakur and Dr.Achintya, Principals, Government Engineering Colleges at Darbhanga and Bhagalpur, for the help and co-operation received during the field work, information shared and extremely useful interactions at Bihar. We are thankful to MPRRDA officers and engineers - Smt Alka Upadhyay, CEO, MPRRDA, S/Shri M.K.Gupta, E-in-C, A.D.Kapale, CGM, D.K.Pachori, CGM, Pavan Jain, K.K.Khare, GM and all their PIU Staff, Prakash Pendre and Govind Sharma, District Mining Officers, Mine and quarry owners, Contractors, STA incharge in Jabalpur and Bhopal, Dr.Nilesh Parikh, Director, MGSIRD, Dr.M.K.Trivedi and other faculty members of Madhav Institute of Science & Technology, Gwalior for their excellent cooperation, help and participation in field work, interactive workshops, data and information provided to CRRI team, extending infrastructure facilities, etc.

Many thanks are due to colleagues, Ms.Sarita Sharma, Mr.Amandeep in CRRI who have contributed immensely towards carrying out various activities in this project.

Director, CSIR-CRRI **Dr. Satish Chandra**

Dr.B.K.Durai, Coordinator, PTA and Head, PME Division

Project Team

Mr.U.K.Guru Vittal, Chief Scientist & Project Leader

Dr.Pankaj Gupta

Mr.Alok Ranjan

Mr.A.K.Sinha

Mr.Nitesh Kumar Goyal

Mr.V.K.Kanaujia

Mr.Amit Kumar

Smt. Rekha

CONTENTS

LIST OF TABLES

LIST OF TABLES (Contd)

LIST OF PHOTOS & FIGURE

LIST OF ABBREVATIONS

AASHTO	American Association of State Highway & Transport Officials
AIV	Aggregate Impact Value
ASTM	American Society for Testing Materials
BC	Black Cotton soil
BRRDA	Bihar Rural Roads Development Agency
CBR	California Bearing Ratio
CRRI	CSIR-Central Road Research Institute
EU	European Union
FI	Flakiness Index
GIS	Geographical Information System
GSB	Granular Sub-Base
HSM	Hard Shoulder Material
IRC	Indian Roads Congress
KTPS	Kahalgaon Thermal Power Station
LL	Liquid limit
MORD	Ministry of Rural Development, Government of India
MPa	Mega Pascals
MPRRDA	Madhya Pradesh Rural Roads Development Authority
MSD	Marble Slurry Dust
NHDP	National Highways Development Programme
NQM	National Quality Monitor
NRRDA	National Rural Roads Development Agency
OB	Over Burden
OMC	Optimum Moisture Content
PI	Plasticity Index
PMGSY	Pradhan Mantri Gram Sadak Yojna
PTA	Principal Technical Agency
RBM	River Borne Material
SGMM	Shri Gulab Mines & Minerals
SP	Special Publication (of Indian Roads Congress)
STA	State Technical Agency
TRL	Transport Research Laboratory
UCS	Unconfined Compressive Strength
U.K	United Kingdom
γ_d	Maximum Dry Density

Preparation of Data-Base of Conventional/ Waste/ Marginal Materials for Construction of Embankment and Pavement Layers

1.0 Introduction

Presently India is experiencing growth in industrial and consumer goods production. To sustain the growth, infrastructure needs are to be strengthened and further expanded. Government of India has taken up NHDP and PMGSY programmes to augment and improve the road infrastructure network in the country. Implementation of these road construction programmes requires huge quantities of road construction materials like aggregates and binder. Demand for all types of aggregates from road construction sector is expected to be about 2300 million cubic tonnes in 2015. Conventionally, hard stone has been used as a road construction material for all categories of roads in the country. Although the hard stone has all the attributes of a good construction material, both in regard to strength and durability, its sources are depleting fast. Moreover, in many parts of the country, leads involved are so long (more than 200 km) that they make the construction costs prohibitive. Economy, durability and quality are prerequisites for overall excellence in accomplishing good road network. Economy, largely depends on the distance of the source of required material. Besides, presently environmental impacts of the aggregate extraction are a source of significant concern across the country. Therefore, there is a pressing need to go in for locally available low grade or marginal materials especially for rural/low volume roads.

National Rural Roads Development Agency (NRRDA) vide their letter dated 27.2.2014 approved the project 'Preparation of Data-Base of Conventional/ Waste / Marginal Materials for Construction of Embankment and Pavement layers' to CRRI vide letter No.P-1002/2/2007-Tech/1341 dated 27.2.2014. The project was sanctioned to determine properties of materials available for road works in two districts of Madhya Pradesh (Jabalpur and Gwalior) and two districts of Bihar (Bhagalpur and Darbhanga). This report contains details of materials collected, characterisation tests conducted on these materials and results and discussion on the same.

2.0 Locally Available/ Marginal Materials

India with its wide variations of climate, topography and geology, relies on a variety of unbound granular materials for construction of different categories of roads. In reality, a wide range of materials are used but the methods of construction and the basic design philosophy are much the same throughout the country. The design and construction procedure commonly adopts ‘premium grade’ granular base course layer overlying a more permeable lesser quality sub-base layer. A premium grade aggregate can be defined as aggregate produced usually from igneous or metamorphic rock but also some times from selected sedimentary rocks or river gravel having very good strength, which after processing contains non plastic fines, is resistant to weathering and when compacted produces a material having soaked CBR value in excess of 100 per cent. Production of such premium grade aggregates is expensive and such materials are not available at many regions. Often readily available construction material do not meet the conventional paving material specifications. Such a situation may warrant that either these substandard materials be used or else a more expensive material must be imported at considerable additional cost. The temptation to use the local materials can be overwhelming, but the decision to use or reject these materials should only be made after a thorough engineering evaluation. This evaluation must determine the engineering characteristics of the materials and must establish how they will affect the design, performance, and construction of pavement. If a substandard material is to be used in the base course, it can be stabilised to improve its quality.

The Permanent International Association of Road Congresses has defined non-standard and non-traditional material as:

"....any material not wholly in accordance with the specifications in use in a country or region for normal road materials but which can be used successfully either in special conditions, made possible because of climatic characteristics or recent progress in road techniques or after having been subject to a particular treatment."

Another definition for marginal material can be 'aggregate produced from a weathered or weathering prone rock, or hard rock containing weathered seams or weaker sedimentary rocks, which after processing contains moderate to high plastic fines, is susceptible to weathering and when compacted has a soaked CBR value between 40 to 100 percent (G.H.Brennan, 1984)

2.1 Usage in sub-base course

The sub-base course acts as secondary load spreading layer in flexible pavement and also as a drainage layer. To ensure drainage function efficiently, the amount of fines (material passing 0.075 mm sieve) must be limited. For well sealed roads in tropical areas, and where surface and road side drains are good, unsaturated moisture conditions prevail and sub-base specifications may be relaxed. The selection of sub-base material will therefore depend on the design function of the layer and the anticipated moisture regime, both in-service and during construction. In many circumstances the requirements of a sub-base are governed by its ability to support construction traffic without excessive deformation or ravelling. A high quality sub-base material is therefore required where loading or climatic conditions are severe. Otherwise, in case of low traffic volume roads, the material requirements for sub-base course can be relaxed.

2.2 Usage in road base

The road base is the main load spreading layer of the pavement. A wide range of materials can be used as unbound road bases including crushed quarried rock, gravels, etc. Alternatively, materials can be stabilised with cement, lime or bitumen. The suitability of materials for use depends primarily on the design traffic level and the local environment. Road bases are expected to conform to specified material gradation and provide high mechanical stability. The grading should contain sufficient low plasticity fines (material passing 425 micron sieve) to produce dense material, with less than 5 per cent air voids when compacted.

3.0 Specifications for Granular / Local Materials Worldwide

The use of granular material in pavement layers can be best accomplished by the development of special design charts or guidelines that are appropriate for prevailing traffic and environmental conditions and afford flexibility for using marginal material. Many marginal materials are moisture sensitive and are not free draining, therefore it is often necessary to design the pavement and pavement layer configurations with the aim of preventing moisture ingress. To compensate for lower strength materials, greater thickness of material may be needed in some circumstances to protect the road from sub-grade deformation. Achieving even higher levels of compaction than those normally specified for sub-base and road bases, could be a relatively cheap method of increasing the stiffness of the pavement and improving performance of certain marginal materials.

A review of marginal material usage worldwide showed that, in Australia CBR requirement for standard granular road base materials is reduced from 80 per cent to 60 per cent when design traffic is less than 1 million standard axles (msa). Design charts for using CBR of 40 per cent in base course have also been developed. In Kenya, relaxed road base requirements apply upto 0.7 msa. Road base materials in Kenya may have a reduced CBR of 50 percent with maximum PI of 15 in wet areas (annual rainfall more than 500 mm) and 20 in dry areas. The maximum particle size is 40 mm and no aggregate particle strength requirements are stated. In case of Botswana, for roads carrying traffic upto 150 vehicles per day, relaxed specification limits for road base include minimum CBR of 45 per cent. In Bangladesh, crushed rock or brick with sand (CBR 60 per cent) is used as road base of low volume sealed roads.

3.1 Specifications in USA

Although each state in USA has a completely independent highway authority, the American Association of Highway and Transportation Officials (AASHTO) and the American Society for Testing Materials (ASTM) have both issued specifications for unbound sub-base and base materials. AASHTO M147 specifies six different grading of aggregates, designated A to F. Grading A is used primarily for base and grading B to D refer to sub-base materials (Table 1). Grading E and F are used as top courses for unsurfaced roads. Other requirements include, liquid limit to be less than 25 per cent, PI to be less than 6 and percentage loss by Los Angeles test to be not greater than 50 per cent. It is pertinent to note that in case of sub-base materials, the per cent finer (maximum limit) has been kept as high as 15 to 20 per cent for 75 micron sieve.

Table – 1 AASHTO Gradation for Base/ Sub-Base

Sieve size	Per cent by weight passing			
	A	**B**	**C**	**D**
50 mm	100	100	100	100
25 mm	–	75 – 95	100	100
9.5 mm	30 – 60	40 – 75	50 – 85	60 – 100
4.75 mm	25 – 55	30 – 60	35 – 65	50 – 85
2.00 mm	15 – 40	20 – 45	25 – 50	40 – 70
0.425 mm	8 – 20	15 – 30	15 – 30	25 – 45
0.075 mm	2 – 8	5 – 20	5 – 15	5 – 20

In ASTM D 2940, two gradations - one for sub-base and the other for base are specified. Many states incorporate some of the AASHTO and ASTM requirements into their specifications. However, with the large variations in geology and climate, the individual specifications used by the state highway authorities differ significantly among the states. Geological differences play an important role: some states, such as Georgia and North Carolina, have abundant supplies of crushed rock and hence prohibit use of gravels. Others, with extensive gravel deposits, do not restrict the use of gravels. However, where gravel is permitted, such states also have a requirement that gravel particles must have atleast one face fractured by crushing.

3.2 British Specifications

The guidelines which were in vogue in U.K, before adoption of EU Guidelines are given in Table 2 and 3. It refers to plasticity limits and material grading requirement. It may be noted that plasticity requirements for road gravels have been defined depending on amount of precipitation and per cent material passing 75 micron sieve can be upto 15 per cent. Presently European Union countries (including U.K) have adopted IS EN 13242, 'Aggregates for Unbound and Hydraulically Bound Materials for Use in Civil Engineering Work and Road Construction'.

Table – 2 Plasticity Requirements for Unbound Aggregates (TRL Road Note 31)

Climate	Liquid Limit	PI
Moist tropical and wet tropical	< 35	< 6
Seasonally wet tropical	< 45	< 12
Arid and semi-arid	< 55	< 20

Table – 3 Gradation Requirements for Natural Road Gravels (TRL Road Note 31)

Sieve size	Per cent by weight passing		
	37.5 mm	20 mm	10 mm
50 mm	100	–	–
Close graded material			
10 mm	45 – 65	55 – 80	25 – 45
425 micron	10 – 25	12 – 27	12 – 30
75 micron	5 – 15	5 – 15	5 – 15

3.3 Specifications in Brazil

Brazil is one of the wettest countries in the world, yet the regional variation is large. Annual rainfall in Brazil varies from more than 3000 mm in some areas to less than 800 mm in some other areas. The material specifications adopted in Brazil for base course are given in Table 4.

Table – 4 Property Requirements for Base Course in Brazil

Criteria	Traffic Category	
	Heavy	Light
CBR (%)	$\geq$ 80	$\geq$ 60
Liquid Limit (%)	< 35	< 40
Plasticity Index	< 10	< 12
Los Angeles abrasion (%)	< 65	< 65
Swell from CBR Test (%)	< 0.2	< 0.2

In case of sub-base course similar specifications are adopted except that CBR requirement is reduced to 20 per cent. The materials gradation adopted is same as AASHTO specification except that grades E and F are not used.

3.4 Specifications in South Africa and Kenya

For use of natural gravel base/sub-bases, in South Africa upto 20 percent of material finer than 75 micron sieve can be used. Plasticity index has been specified to be between 13 to 20, depending upon rainfall. In Kenya, PI value specified is less than 15 in wetter areas and less than 20 in dry Areas.

4.0 Using Locally Available Materials as per IRC Codes and Specifications

4.1 Provisions in IRC Special Publication (SP):72

The Indian Roads Congress (IRC) / NRRDA guidelines advocate use of locally available materials. IRC SP:72, 'Guidelines for Design of Flexible Pavements for Rural Roads', states that by maximising the use of locally available materials, suitable and economical designs can be worked out. IRC SP:72 classify the locally available materials into following six categories:

(a) Selected granular soil for use in subgrade

(b) Soil stabilisation – Mechanical and using additives

(c) Naturally occurring softer aggregates like moorum, kankar, gravel, etc.

(d) Brick and over burnt brick metal

(e) Stone metal

(f) Industrial waste

The manner of using soft aggregates, as enunciated in IRC SP:72 is given in Table 5. Further, while dealing with design of gravel/ soil-gravel roads, IRC SP:72 states that, 'minimum soaked CBR of 80 per cent for the gravel base material is often considered an additional requirement'. The grading requirement for gravel base restricts percentage passing 425 micron sieve to 21 per cent and 75 micron sieve to 8 per cent.

In India, Specifications and Guidelines regarding road construction materials, state the properties of the material to be used for a given purpose and it is assumed that if a material meets all the specification requirements it will perform satisfactorily. This is based on satisfactory performance of such materials as observed over many years and such an approach suits 'premium grade' materials. However, for minor roads judicious relaxation of the requirements given in the specification is a possibility that could lead to greater use of marginal materials which do not fully comply. However, until recently, the specifications for marginal materials (fines content, plasticity, etc) were being kept same as premium grade materials (Table 5).

Table – 5 Manner of using Soft Aggregates in Road Pavement (IRC SP:75)

Material Occurs as	Manner of Using	Test/ Quality Requirement
In block or large discrete particles	As WBM without screenings/ filler as per IRC:19, after crushing to required size	Wet AIV not to exceed 50, 40 or 30 when used in sub-base, base and surfacing respectively
Graded form without appreciable amount of soil	As GSB layer or for base/ surfacing	PI < 6 for base/sub-base, PI between 4 to 10 for surfacing. Soaked CBR to be strength test
As discrete particles mixed with appreciable amount of soil such as soil-gravel mixtures	Directly as soil-gravel mix for sub-base, base or surfacing	Should be well graded and PI < 6 base/ sub-base, PI between 4 to 10 for surfacing. Soaked CBR to be strength Test

4.2 Revised Specifications for Rural Roads In India

'Specifications for Rural Roads' was first published in the year 2004 by the Indian Roads Congress. During the last decade, significant developments have taken place in rural road sector and about 4 lakh km of rural roads have been constructed or upgraded under PMGSY. Based on experiences gained, feedback received and developments in technology, First revision of Specifications for Rural Roads was published in 2014. In this revision, special emphasis has been given for use of locally available/ marginal materials. Some of the important changes incorporated to promote use of locally available marginal in the first revision are given below:

- Upper limit for material finer than 75 micron sieve for sub-base layer increased to 15 per cent, which was previously kept at 10 per cent.
- Variable 'Liquid Limit (LL) and Plasticity Index (PI)' depending on annual rainfall introduced for Granular Sub-Base (GSB). Previously LL was 25% (Max) and 6 (Max) throughout India. Now for low rainfall areas (annual rainfall less than 1000 mm) LL can be 40% (max) and PI can be 15 (max). For areas having rainfall more than 1000 mm rainfall, LL can be 35% (max) and PI can be 10 (max).
- For Soil-Aggregate mixes to be used in lower base course layer, CBR requirement revised to 50% minimum, and for upper base 80% minimum. Previously the CBR limit for base course material (both lower and upper base course layers) was 80% minimum.
- Different kinds of material specifications like Soil-Aggregate, Gravel, GSB, etc having different gradations (both open and close graded) are now available so that naturally occurring materials satisfying any of these gradations can be used suitably either in sub-base or base course layers.

The above modifications are expected to boost usage of locally available / marginal materials. However, to kick-start such usage, data base of locally available materials is required.

5.0 Study Districts Selected

Recognising the need to have a compiled data of locally available waste/marginal materials available in different parts of the country, which can help the authorities to explore the possibilities of their usage in different layers of road pavement, NRRDA sponsored an R&D project to CRRI for preparation of such data base. Based on discussions held at NRRDA, it was decided that the data would be collected district wise. Presently there are about 676 districts in India. Hence it was decided that, to start the data base preparation activities, the project would be taken up as a pilot project in four districts of two states. Accordingly, study was taken up in Bhagalpur and Darbhanga districts in Bihar and Gwalior and Jabalpur districts in Madhya Pradesh. Brief details of these districts are presented below.

5.1 Darbhanga District

Darbhanga district is one of the thirty-eight districts of Bihar state in eastern India, and Darbhanga city is the administrative headquarters of this district. The district is located North of Ganga river, bounded on the north by Madhubani district, on the south by Samastipur district, on the east by Saharsa district and on the west by Sitamarhi and Muzaffarpur districts. The district covers an area of 2,279 km². Darbhanga district has a vast alluvial plain devoid of any hills. There is a gentle slope from north to south with a depression in the centre. The ground elevation in the entire district is about 50 m above mean sea level. This district gets flooded almost every year. Though numerous rivers originating in the Himalayas water this district, it has four major river systems, the Bagmati, the little Bagmati, the Kamla and the Tiljuga. May is the hottest month of the year when the temperature goes up to 47°C. Rain sets in towards the middle of June. Average annual rainfall of this district is about 1150 mm. Around 92 per cent of the total rainfall is received during monsoon months (June to October). Agriculture is the primary occupation of the majority of the population of this district, major crop being rice. Other crops produced in this district are wheat, maize, pulses, oil seeds and sugarcane. No major industry is located in the district nor does it has any deposits of major minerals.

5.2 Bhagalpur District

Bhagalpur was another district selected in Bihar state. Bhagalpur town is administrative headquarters of this district. Bhagalpur is located in the southern region of Bihar. The district is surrounded by Munger, Khagaria, Madhepura, Purnea, Kathiarand Banka districts of Bihar and Godda and Sahebganj districts of Jharkhand. It is one of the oldest districts of Bihar and is situated in the Ganga basin at about 45 m above the sea level. The river Ganges flows through this district. In southern side of the district, hills rising to about 150-200 m above mean sea level are seen, otherwise the district is a river plain made by river Ganga. Bhagalpur district occupies an area of 2,569 square kilometres. The NTPC thermal power plant at Kahalgaon is in Bhagalpur district. During 2010-11, this power plant produced about 3.81 million tonnes of fly ash (all types of ash - fly ash, bottom ash and pond ash included) out of which 0.91 million tonnes of ash was utilised. The Gangetic plains are very fertile and the main crops include rice, wheat, maize, barley, and oilseeds. The economy of Bhagalpur is dependent mainly on agriculture and silk. Annual rainfall of the district is about 1170 mm and maximum temperature in summer is about 44.5^0 C. As informed to CRRI team, stone/ moorum quarries seen near Shahkund in southern part of district are presently not in operation.

5.3 Gwalior District

Gwalior district is one of the 50 districts of Madhya Pradesh state in central India. The historic city of Gwalior is its administrative headquarters. The district has an area of 5,214 km². Gwalior District is bounded by the districts of Bhind to the northeast, Datia to the east, Shivpuri to the south, Sheopur to the east, and Morena to the northwest. The district is relatively plain area (central India plateau). This plain, though broken in its southern portion by low hills. The district has an elevation varying from 200 to 300 m above mean sea level while highlands have an elevation of about 400 m above mean sea level. In the summer season the climate is very hot, the shade temperature rising frequently to around 44°C, but in the winter months (from November to February inclusive) it is usually temperate and for short periods extremely cold. The average annual rainfall in Gwalior is about 760 mm, most of which occurs in Monsoon (June to September). Different types of minerals available in Gwalior district include Moorum, different types of stones, iron ore, sand and fire clay. The soil in the district is predominantly black cotton soil produced as a result of weathering of basalt.

5.4 Jabalpur District

Jabalpur District is in Madhya Pradesh state in central India. The city of Jabalpur is the administrative headquarters of the district. The area of this district is 10,160 km². Jabalpur District is located in the Mahakoshal region of Madhya Pradesh, on the divide between the watersheds of Narmada and the Son, but mostly within the valley of the Narmada, which here runs through the famous gorge known as the 'Bheda Ghat' (Marble rock). The district area comprises of a long narrow plain flanked by highlands. This plain, which forms an offshoot from the great valley of the Narmada, is covered in its western and southern portions by a rich alluvial deposit of black cotton-soil. The average elevation of plains varies from 300 to 450 m above mean sea level while hillocks of height upto 750 m are also seen. Average annual rainfall in the district is about 1060mm and highest temperature during summer is about 41^0 C. There are many iron ore mines in the district and total production of iron ore (2010-11) was about 1.5 million tonnes. apart from that, fireclay, dolomite, laterite and manganese are also mined. Minor minerals include sand, hard stones (basalt), moorum and marble.

6.0 Collection of Material Samples

After collecting and studying available literature on road construction material availability in the four selected districts, CRRI team visited each of these districts and concerned state capitals. Extensive discussions were held with engineers and officers dealing with PMGSY works to elicit information about road construction material availability in selected districts. Since stone aggregates, sand and moorum are considered as minor minerals, meetings were also held with officers of concerned state mining and geology department officers to obtain information regarding availability of road construction materials in those districts. Meetings were held with concerned academic faculty of STAs also to obtain information about road construction material availability. After such consultations, the following materials were collected from the respective districts:

6.1 Darbhanga District

(1) In-Situ (Local) Soil – Akbarpur Village (Rampur Tola) (Coordinates - 26.064301, 85.941403) and Pakahi Village (Coordinates - 25.790463, 86.239843)

(2) Brickbats – Sahora Village (Coordinates - 26.056436, 85.935574)

(3) Bagmati River Sand (Collected near Ashok Paper Mills) (Coordinates - 26.037583, 85.886664)

(4) Stone metal which is being presently used in road works (Sourced from Mirza Chowki, Bhagalpur-Jharkhand Border) Collection point Anandpur Village (Coordinates - 26.061371, 85.939172)

6.2 Bhagalpur District

(1) In-Situ (Local) Soil – Jagarnathpur Village (Coordinates - 25.128513, 86.88162)

(2) Stone quarry waste rock+ soil mix, Local moorum type soil from stone quarry and Stone metal from the quarry (Quarry presently not in operation) – Shahkund (Coordinates - 25.153171, 86.81104)

(3) Fly ash and Pond ash from Kahalgaon Thermal Power Station under NTPC (Coordinates - 25.225985, 87.237024)

Photo - 1 Collection of Pond ash from Kahalgaon Thermal Power Station

Photo - 2 Abandoned Stone Quarry at Shahkund

Photo - 3 Collection of Bagmati River Sand

6.3 Gwalior District

(1) Basalt stone quarry waste from Nayagaon Village (Stone chips mixed with soil - OB Material) (Coordinates - 26.110886, 78.077487)

(2) Iron ore mine over burden (OB) waste from Panihar Village (Coordinates - 26.083672, 78.056131)

(3) Dolomite stone quarry waste from Bilaua Village - Two types (Moorum type soil and Stone chips mixed with soil) (Coordinates - 26.038056, 78.307222)

(4) Flaky type sand stones (Coordinates - 26.111389, 78.076111)

6.4 Jabalpur District

(1) Iron ore mine OB Waste from three mines (SGMM (Gulab) Mines - Coordinates 23.36296, 80.035304, Jakhodia Mines - Coordinates 23.365245, 80.038971, Srivastava Mines - Coordinates 23.398009, 80.054228)

(2) River borne material (RBM) from Singauri Village PMGSY Road (Coordinates - 23.276437, 79.654484)

(3) Phyllite type rock mixed with soil / Probably low grade iron ore mine waste (being used for hard shoulder) from Bargawa PMGSY Road (Coordinates - 23.5632, 80.016518)

(4) Black cotton (BC) soil - (Coordinates - 23.364319, 80.054762)

(5) Marble quarry overburden rock from Rajas Marbles, Ghutehi Village, (Coordinates - 23.577282, 80.110073)

(6) Phyllite rock (Soft) from Bargawa PMGSY Road (Coordinates - 23.5632, 80.016518)

Photo - 4 Interactive Workshop at MITS, Gwalior

Photo - 5 Stacking of Overburden Material by the side or Iron Ore Mine at Jabalpur

Photo - 6 Stacking of OB Rock at Marble Mine (Jabalpur)

Photo - 7 Collection of Stone Quarry Waste at Gwalior

7.0 Laboratory Characterisation of Collected Materials

For determination of physical and engineering properties, soil, moorum type material or soil mixed with stone chips (OB waste) were subjected to the following tests as per Bureau of Indian Standards (ISI) codes given below:

(i)	Grain size analysis	IS 2720 (Part 4)
(ii)	Atterberg Limits	IS 2720 (Part 5)
(iii)	Moisture-Density Relationship (Proctor Light Compaction Test)	IS 2720 (Part 7)
(iv)	Moisture-Density Relationship (Proctor Heavy Compaction Test)	IS 2720 (Part 8)
(v)	California Bearing Ratio(CBR) Test	IS 2720 (Part 16)
(vi)	Specific Gravity	IS 2720 (Part 3)
(vii)	Direct Shear Test	IS 2720 (Part 13)
(viii)	Permeability Test	IS 2720 (Part 17)

Stone aggregate type samples collected were subjected to following tests as per Bureau of Indian standards.

(i) Specific gravity

(ii) Water absorption after soaking in water for different time periods

(iii) Aggregate impact value test (in dry as well as after soaking depending upon aggregate type)

Stabilisation techniques are adopted to improve the strength properties of pavement materials for incorporating them in the base / sub-base layers of the road pavement. Cement stabilisation is most commonly adopted to improve properties of marginal materials and make the amenable to usage in road pavement. Samples of pond ash and fly ash from Kahalgaon TPS and locally available soil from Bhagalpur district, Bagmati river sand + Brickbats mixture (60%+40%) from Darbhanga district, Iron ore mine waste and Basalt stone quarry waste from Gwalior district, RBM, iron ore mine OB waste and hard shoulder material were stabilised by using different percentages of cement. Grade 43 cement was used for stabilisation. Unconfined compressive strength (UCS) tests as per IS 4332 Part V at different time periods of curing and durability test as per IRC SP:89 were conducted on these cement stabilised samples. Curing of these samples was carried out under humid conditions in an enclosed chamber before determining compressive strength of the specimens. The results of the tests are given district wise. Additionally, material property data for conventional road construction materials in these four districts was collected from respective PIUs/ National Quality Monitor (NQM) test reports. This data has also been presented in following pages.

7.1 Darbhanga District Material Sample Results

Table – 6 (a) Physical & Engineering Properties of Darbhanga District Local Soil

Property		**Akbarpur Village Soil (Rampur Tola – Hayaghat)**	**Test Method**
Coordinates		26.064301, 85.941403	
Specific gravity		2.58	IS 2720 - Part 3
Liquid Limit (%)		25	IS 2720 - Part 5
Plasticity Index		7	
Gradation	Gravel (%)	1	IS 2720 - Part 4
	Sand (%)	11	
	Silt (%)	68	
	Clay (%)	20	
Standard Proctor Test – γ_d kN/m^3		17.6	IS 2720 - Part 7
OMC (%)		15.9	
Modified Proctor Test – γ_d kN/m^3		19.3	IS 2720 - Part 8
OMC (%)		10.5	
CBR (%) At 100% Standard Proctor Density		5	IS 2720 - Part 16
CBR (%) At 98% Modified Proctor Density		7	
Direct Shear Test	Cohesion C (kN/m^2)	7	IS 2720 - Part 13
	ϕ	13.4^0	
Permeability (m/day)		1.20×10^{-3}	IS 2720 - Part 17

Table – 6 (b) Physical & Engineering Properties of Local Soil (Sample 2)

Property		Pakahi Village Soil	Test Method
Coordinates		25.790463, 86.239843	
Specific gravity		2.64	IS 2720 - Part 3
Liquid Limit (%)		32	IS 2720 - Part 5
Plasticity Index		10	
Gradation	Gravel (%)	1	IS 2720 - Part 4
	Sand (%)	10	
	Silt (%)	73	
	Clay (%)	16	
Standard Proctor Test – γ_d kN/m^3 OMC (%)		18.3 14.3	IS 2720 - Part 7
Modified Proctor Test – γ_d kN/m^3 OMC (%)		19.5 10.3	IS 2720 - Part 8
CBR (%) At 100% Standard Proctor Density		4	IS 2720 - Part 16
CBR (%) At 98% Modified Proctor Density		6	
Direct Shear Test	Cohesion C (kN/m^2)	4	IS 2720 - Part 13
	ϕ	26.1^0	

Table – 7 Physical & Engineering Properties of Bagmati River Sand

Property		Bagmati river sand	Test Method
Coordinates		26.037583, 85.886664	
Specific gravity		2.65	IS 2720 - Part 3
Liquid Limit (%)		33	IS 2720 - Part 5
Plasticity Index		N P	
Gradation	Gravel (%)	0	IS 2720 - Part 4
	Sand (%)	32	
	Silt (%)	49	
	Clay (%)	9	
Standard Proctor Test – γ_d kN/m^3 OMC (%)		15.8 17.2	IS 2720 - Part 7
Modified Proctor Test – γ_d kN/m^3 OMC (%)		16.9 13.2	IS 2720 - Part 8
CBR (%) At 100% Standard Proctor Density		10	IS 2720 - Part 16
CBR (%) At 98% Modified Proctor Density		15	
Direct Shear Test	Cohesion C (kN/m^2)	3	IS 2720 - Part 16
	ϕ	27^0	
Permeability (m/day)		36 x 10^{-3}	IS 2720 - Part 17

Table – 8 Unconfined Compressive Strength of Cement Stabilised Darbhanga Samples

Type of Material		**Bagmati river sand + Brick Bats (60%+40%)**
Coordinates		26.037583, 85.886664
UCS after 3 days curing (MPa)	3% Cement	0.25
	6% Cement	0.70
	9% Cement	1.51
UCS after 7 days curing (MPa)	3% Cement	0.52
	6% Cement	0.81
	9% Cement	1.81
UCS after 14 days curing (MPa)	3% Cement	0.62
	6% Cement	1.01
	9% Cement	2.20

Table – 9 Durability Test on Cement Stabilised Darbhanga Samples

Type of Material	**Coordinates**	**Durability (% of UCS Strength - Immersed sample/moist cured sample)**		
		3% Cement	**6% Cement**	**9% Cement**
Bagmati river sand + Brickbats	26.037583,85.886664	90	89	83

Table – 10 Properties of Stone Aggregates (Jharkhand) Being Used in Darbhanga

Test	**Test Result for Stone Aggregates**
Coordinates (Sample Collection Point)	26.061371, 85.939172
Specific Gravity	2.759
Water absorption (%) After Soaking Aggregates for 1 Day After Soaking Aggregates for 1 Day	 0.5 0.6
Aggregate impact value (In Dry State - %)	10.1
Aggregate impact value (After Soaking - %) After Soaking Aggregates for 1 Day After Soaking Aggregates for 1 Day	 - 9.25

Table – 11 Properties of Brickbats (Darbhanga)

Test	**Test Result for Brickbats**
Coordinates	26.056436, 85.935574
Specific Gravity	2.13
Water absorption (%) After Soaking Aggregates for 1 Day After Soaking Aggregates for 1 Day	 13.0 14.0
Aggregate impact value (In Dry State - %)	31.0
Aggregate impact value (After Soaking - %) After Soaking Aggregates for 1 Day After Soaking Aggregates for 1 Day	 31.9 33.6

Table – 12 Properties of Bagmati River Sand (60%) + Brickbats (40%) Mix

Test	Sand + Brickbats Mix (60:40)
Coordinates	26.056436, 85.935574
Standard Proctor Test – γ_d kN/m^3 OMC (%)	16.5 14.0
CBR (%) At 100% Standard Proctor Density	23

Table - 13 Test Results on Conventional Materials from Darbhanga (From NQM Reports)

Package No BR10R-254, 269 & 291 - Coordinates: Lat 26.169779, Long - 85.980359	
GSB - Gradation (Trail 1)	
Sieve Size	Per cent Passing
53 mm	100
26.5 mm	54
4.75 mm	40
75 microns	0
GSB - Gradation (Trail 2)	
53 mm	99
26.5 mm	51
4.75 mm	33
75 microns	0
GSB - Gradation (Trail 3)	
53 mm	100
26.5 mm	51
4.75 mm	27
75 microns	0
WBM Stone Metal (Grade 2) - Gradation (Trail 1)	
Sieve Size	Per cent Passing
90 mm	100
63 mm	94
53 mm	75
45 mm	26
22.4 mm	4
WBM Stone Metal (Grade 2) - Gradation (Trail 2)	
90 mm	100
63 mm	90
53 mm	57
45 mm	20
22.4 mm	5
WBM Stone Metal (Grade 2) - Gradation (Trail 3)	
90 mm	100
63 mm	92
53 mm	73
45 mm	20
22.4 mm	3

Table - 13 Test Results on Conventional Materials from Darbhanga (From NQM Reports..Contd)

WBM Stone Metal (Grade 3) - Gradation	
Sieve Size	Per cent Passing
63 mm	100
53 mm	95
45 mm	66
22.4 mm	8
11.2 mm	0
Degree of compaction of Subgrade soil (%)	103 and 101
Degree of compaction of GSB (%)	100

7.2 Bhagalpur Material Sample Results

Table – 14 Physical & Engineering Properties of Local Soil - Jagarnathpur Village

Property		Local Soil - Jagarnathpur Village
Coordinates		25.128513, 86.88162
Specific gravity		2.62
Liquid Limit (%)		31
Plasticity Index		12
Gradation	Gravel (%)	0
	Sand (%)	13
	Silt (%)	71
	Clay (%)	16
Standard Proctor Test – γ_d kN/m^3 OMC (%)		18.5 12.5
Modified Proctor Test – γ_d kN/m^3 OMC (%)		19.7 9.5
CBR (%) At 100% Standard Proctor Density		5
CBR (%) At 98% Modified Proctor Density		7

Table – 15 Physical & Engineering Properties of Stone Quarry Waste - Shahkund

Property		Stone Quarry Waste - Shahkund
Coordinates		25.153171, 86.81104
Specific gravity		2.64
Liquid Limit (%)		28
Plasticity Index		10
Gradation	Gravel (%)	55
	Sand (%)	21
	Silt (%)	21
	Clay (%)	3
Standard Proctor Test – γ_d kN/m^3 OMC (%)		19.8 9.0
Modified Proctor Test – γ_d kN/m^3 OMC (%)		20.7 7.5
CBR (%) At 100% Standard Proctor Density		10
CBR (%) At 98% Modified Proctor Density		18

Table – 16 (a) Physical & Engineering Properties of Fly ash from Kahalgaon Thermal Power Station

Property		Fly ash from KTPS
Coordinates		25.225985, 87.237024
Specific gravity		1.98
Liquid Limit (%)		44
Plasticity Index		N P
Gradation	Gravel (%)	0
	Sand (%)	7
	Silt (%)	86
	Clay (%)	7
Standard Proctor Test – γ_d kN/m^3 OMC (%)		13.7 18.5
Modified Proctor Test – γ_d kN/m^3 OMC (%)		14.1 15.5
CBR (%) At 100% Standard Proctor Density		2
CBR (%) At 98% Modified Proctor Density		2.5
Direct Shear Test	Cohesion C (kN/m^2)	0
	ϕ	29^0
Permeability (m/day)		9×10^{-3}

Table – 16 (b) Physical & Engineering Properties of Pond ash from Kahalgaon Thermal Power Station

Property		Pond ash from KTPS
Coordinates		25.225985, 87.237024
Specific gravity		2.15
Liquid Limit (%)		32
Plasticity Index		N P
Gradation	Gravel (%)	0
	Sand (%)	26
	Silt (%)	68
	Clay (%)	6
Standard Proctor Test – γ_d kN/m^3 OMC (%)		12.6 24.5
Modified Proctor Test – γ_d kN/m^3 OMC (%)		14.5 16.0
CBR (%) At 100% Standard Proctor Density		6
CBR (%) At 98% Modified Proctor Density		7
Direct Shear Test	Cohesion C (kN/m^2)	0
	ϕ	31^0
Permeability (m/day)		22×10^{-3}

Table – 17 Physical & Engineering Properties of Local Moorum (Stone Quarry - Shahkund)

Property		Moorum type Quarry OB - Shahkund
Coordinates		25.153171, 86.81104
Specific gravity		2.64
Liquid Limit (%)		26
Plasticity Index		9
Gradation	Gravel (%)	27
	Sand (%)	33
	Silt (%)	30
	Clay (%)	10
Standard Proctor Test – γ_d kN/m^3 OMC (%)		20.1 10.0
Modified Proctor Test – γ_d kN/m^3 OMC (%)		22.0 7.4
CBR (%) At 100% Standard Proctor Density		12
CBR (%) At 98% Modified Proctor Density		20

Table – 18 (a) Unconfined Compressive Strength of Cement Stabilised Pond ash - KTPS

Type of Material		Pond ash - KTPS
Coordinates		25.225985, 87.237024
UCS of Unstabilised Sample		0.04
UCS after 3 days curing (MPa)	3% Cement	0.25
	6% Cement	0.63
	9% Cement	1.03
UCS after 7 days curing (MPa)	3% Cement	0.45
	6% Cement	0.83
	9% Cement	1.40
UCS after 14 days curing (MPa)	3% Cement	0.59
	6% Cement	1.07
	9% Cement	2.01

Table – 18 (b) Unconfined Compressive Strength of Cement Stabilised Fly ash - KTPS

Type of Material		Fly ash - KTPS
Coordinates		25.225985, 87.237024
UCS of Unstabilised Sample		0.05
UCS after 3 days curing (MPa)	3% Cement	0.46
	6% Cement	0.84
	9% Cement	1.56
UCS after 7 days curing (MPa)	3% Cement	0.71
	6% Cement	1.54
	9% Cement	1.98
UCS after 14 days curing (MPa)	3% Cement	0.80
	6% Cement	2.47
	9% Cement	4.00

Table – 18 (c) Unconfined Compressive Strength of Cement Stabilised Local Soil - Jagarnathpur

Type of Material		**Local Soil - Jagarnathpur**
Coordinates		25.128513, 86.88162
UCS of Unstabilised Sample		0.22
UCS after 3 days curing (MPa)	3% Cement	0.63
	6% Cement	1.00
	9% Cement	1.55
UCS after 7 days curing (MPa)	3% Cement	0.75
	6% Cement	1.38
	9% Cement	1.81
UCS after 14 days curing (MPa)	3% Cement	0.78
	6% Cement	1.53
	9% Cement	1.91

Table – 19 (a) Durability Test on Cement Stabilised Pond ash - KTPS

Type of Material	**Coordinates**	**Durability (% of UCS Strength - Immersed sample/moist cured sample)**		
		3% Cement	**6% Cement**	**9% Cement**
Pond ash - KTPS	25.225985, 87.237024	94	88	80

Table – 19 (b) Durability Test on Cement Stabilised Fly ash - KTPS

Type of Material	**Coordinates**	**Durability (% of UCS Strength - Immersed sample/moist cured sample)**		
		3% Cement	**6% Cement**	**9% Cement**
Fly ash - KTPS	25.225985, 87.237024	76	85	96

Table – 19 (c) Durability Test on Cement Stabilised Local Soil - Jagarnathpur

Type of Material	**Coordinates**	**Durability (% of UCS Strength - Immersed sample/moist cured sample)**		
		3% Cement	**6% Cement**	**9% Cement**
Local Soil - Jagarnathpur	25.128513, 86.88162	52	76	81

Table – 20 Properties of Stone Aggregates (Shahkund Quarry - Not in Operation)

Tests	**Shahkund Quarry Stone Aggregates**
Coordinates	25.153171, 86.81104
Specific Gravity	2.97
Water Absorption (After Soaking for 3 days - %)	1.7
Aggregate Impact Value (In Dry State - %)	19
Aggregate Impact Value (After Soaking for 3 days - %)	20

Table - 21 (a) WBM Aggregates and GSB Gradation from Bhagalpur (From NQM Reports)

Package No BR06R-315 and 320 - Coordinates: Lat 25.117367, Long - 86.702780	
WBM Stone Metal (Grade 2) - Gradation	
Sieve Size	Per cent Passing
90 mm	100
63 mm	92
53 mm	72
45 mm	12
22.4 mm	1
WBM Stone Metal (Grade 3) - Gradation	
Sieve Size	Per cent Passing
63 mm	100
53 mm	97
45 mm	72
22.4 mm	9
11.2 mm	5
GSB (Grade 3) - Gradation	
Sieve Size	Per cent Passing
53 mm	100
26.5 mm	59
4.75 mm	29
75 microns	1

Table - 21 (b) WBM Aggregates Gradation (Submitted by Bhagalpur PIU)

Coordinates: Lat 25.251559, Long - 87.012809	
WBM Stone Metal (Grade 2) - Gradation	
Sieve Size	Per cent Passing
90 mm	100
63 mm	92
53 mm	33
45 mm	13
22.4 mm	4
WBM Stone Metal (Grade 3) - Gradation	
Sieve Size	Per cent Passing
63 mm	100
53 mm	95
45 mm	78
22.4 mm	8
11.2 mm	4

7.3 Gwalior Material Sample Results

Table – 22 (a) Physical & Engineering Properties of Bilaua Stone Quarry Waste (Type 1 OB - Stone chips + Soil)

Property		Stone quarry waste (Type 1) excavated along with over burden (Bilaua Quarry)	Test Method
Coordinates		26.038056, 78.307222	
Specific gravity		2.81	IS 2720 - Part 3
Liquid Limit (%)		23	IS 2720 - Part 5
Plasticity Index		N P	
Gradation	Gravel (%)	38	IS 2720 - Part 4
	Sand (%)	44	
	Silt (%)	15	
	Clay (%)	3	
Standard Proctor Test – γ_d kN/m^3 OMC (%)		21.3 8.5	IS 2720 - Part 7
Modified Proctor Test – γ_d kN/m^3 OMC (%)		21.7 6.0	IS 2720 - Part 8
CBR (%) At 100% Standard Proctor Density		45	IS 2720 - Part 16
CBR (%) At 98% Modified Proctor Density		47	
Direct Shear Test	Cohesion C (kN/m^2)	4	IS 2720 - Part 13
	ϕ	34^0	
Permeability (m/day)		17.8 x 10^{-3}	IS 2720 - Part 17

Table – 22 (b) Physical & Engineering Properties of Bilaua Stone Quarry Waste (Type 2 OB - Stone chips + Soil)

Property		Stone quarry Waste (Type 2) Moorum type Material - Bilaua Quarry	Test Method
Coordinates		26.038056, 78.307222	
Specific gravity		2.60	IS 2720 - Part 3
Liquid Limit (%)		25	IS 2720 - Part 5
Plasticity Index		7	
Gradation	Gravel (%)	11	IS 2720 - Part 4
	Sand (%)	75	
	Silt (%)	10	
	Clay (%)	4	
Standard Proctor Test – γ_d kN/m^3 OMC (%)		19.7 10.8	IS 2720 - Part 7
Modified Proctor Test – γ_d kN/m^3 OMC (%)		20.5 7.2	IS 2720 - Part 8
CBR (%) At 100% Standard Proctor Density		40	IS 2720 - Part 16
CBR (%) At 98% Modified Proctor Density		43	
Direct Shear Test	Cohesion C (kN/m^2)	11	IS 2720 - Part 13
	ϕ	31^0	
Permeability (m/day)		93 x 10^{-3}	IS 2720 - Part 17

Table – 22 (c) Physical & Engineering Properties of Nayagaon Stone Quarry Waste (OB - Stone chips + Soil)

Property		Basalt Quarry Over burden waste – Soil mixed with stone chips from Nayagaon	Test Method
Coordinates		26.110886, 78.077487	
Specific gravity		2.77	IS 2720 - Part 3
Liquid Limit (%)		25	IS 2720 - Part 5
Plasticity Index		N P	
Gradation	Gravel (%)	66	IS 2720 - Part 4
	Sand (%)	26	
	Silt (%)	7	
	Clay (%)	1	
Standard Proctor Test – γ_d kN/m^3 OMC (%)		21.5 11.5	IS 2720 - Part 7
Modified Proctor Test – γ_d kN/m^3 OMC (%)		22.4 7.8	IS 2720 - Part 8
CBR (%) At 100% Standard Proctor Density		21	IS 2720 - Part 16
CBR (%) At 98% Modified Proctor Density		29	
Direct Shear Test	Cohesion C (kN/m^2)	0	IS 2720 - Part 13
	ϕ	36^0	
Permeability (m/day)		38 x 10^{-3}	IS 2720 - Part 17

Table – 23 Physical & Engineering Properties of Panihar Iron Ore Mine Over Burden Waste

Property		Iron Ore Mine OB Waste (Panihar, Gwalior District)	Test Method
Coordinates		26.083672, 78.056131	
Specific gravity		2.93	IS 2720 - Part 3
Liquid Limit (%)		37	IS 2720 - Part 5
Plasticity Index		17	
Gradation	Gravel (%)	57	IS 2720 - Part 4
	Sand (%)	22	
	Silt (%)	14	
	Clay (%)	7	
Standard Proctor Test – γ_d kN/m^3 OMC (%)		21.6 13.0	IS 2720 - Part 7
Modified Proctor Test – γ_d kN/m^3 OMC (%)		23.5 9.4	IS 2720 - Part 8
CBR (%) At 100% Standard Proctor Density		25	IS 2720 - Part 16
CBR (%) At 98% Modified Proctor Density		29	
Direct Shear Test	Cohesion C (kN/m^2)	17	IS 2720 - Part 13
	ϕ	34^0	
Permeability (m/day)		18 x 10^{-3}	IS 2720 - Part 17

Table – 24 (a) Unconfined Compressive Strength of Cement Stabilised Gwalior Samples

Type of Material		Iron Ore Mine OB Waste
Coordinates		26.083672, 78.056131
UCS without additive (MPa)		0.32
UCS after 3 days curing (MPa)	3% Cement	1.16
	6% Cement	1.98
	9% Cement	2.57
UCS after 7 days curing (MPa)	3% Cement	1.80
	6% Cement	2.61
	9% Cement	2.83
UCS after 14 days curing (MPa)	3% Cement	2.01
	6% Cement	2.85
	9% Cement	3.95

Table – 24 (b) Unconfined Compressive Strength of Cement Stabilised Gwalior Samples

Type of Material		Basalt Stone Quarry Waste
Coordinates		26.110886, 78.077487
UCS without additive (MPa)		0.17
UCS after 3 days curing (MPa)	3% Cement	1.21
	6% Cement	2.37
	9% Cement	3.52
UCS after 7 days curing (MPa)	3% Cement	1.41
	6% Cement	3.01
	9% Cement	4.01
UCS after 14 days curing (MPa)	3% Cement	1.67
	6% Cement	4.05
	9% Cement	4.63

Table – 25 Durability Test on Cement Stabilised Gwalior Samples

Type of Material	Coordinates	Durability (% of UCS Strength - Immersed /moist cured)		
		3% Cement	6% Cement	9% Cement
Iron Ore Mine OB Waste	26.083672, 78.056131	98	93	87
Basalt Stone Quarry Waste	26.110886, 78.077487	88	83	87

Table – 26 Properties of Sand Stone - Gwalior

Tests	Sand Stone (Flaky)
Coordinates	26.111389, 78.076111
Specific Gravity	2.60
Water Absorption After Soaking for 1 days - % After Soaking for 3 days - %	 4.9 5.3
Aggregate Impact Value (In Dry State - %)	19.0
Aggregate Impact Value (After Soaking for 3 days - %)	23.0

Table – 27 (a) Properties of Local Soil and Conventional Hard Aggregates (Data From PIU)

Package No 1419 (NH 92 to Dang Guthina) - Coordinates: Lat 26.324545, Long 78.302636	
Properties of Local Soil	
Liquid Limit (%)	34.0
Plastic Limit (%)	16.8
Plasticity Index	17.2
Standard Proctor Test (Sample 1) - MDD (kN/m^3)	18.95
OMC (%)	12.25
Standard Proctor Test (Sample 2) - MDD (kN/m^3)	18.63
OMC (%)	12.45
Degree of Compaction achieved in the field (%)	99
CBR (%)	8.0
Hard Shoulder Material	
CBR (%)	13.0
WBM Stone Metal (Grade 2) - Gradation	
Sieve Size	Per cent Passing
90 mm	100
63 mm	94
53 mm	60
45 mm	10
22.4 mm	4
WBM Stone metal - Water Absorption (%)	1.38 (Grade 3) 1.40 (Grade 2)

Table – 27 (b) Properties of Local Soil and Conventional Hard Aggregates (Data From PIU)

Package No 1425 (Dabra Road to Badera Khurd) - Coordinates: Lat 25.936104, Long 78.39041	
Properties of Local Soil	
Liquid Limit (%)	35.5
Plastic Limit (%)	20.5
Plasticity Index	15.0
CBR (%)	5.0
Hard Shoulder Material	
CBR (%)	13.0
Degree of compaction of hard shoulder (%)	100
WBM Stone Metal (Grade 2) - Gradation	
Sieve Size	Per cent Passing
90 mm	100
63 mm	93
53 mm	43
45 mm	11
22.4 mm	3
WBM Stone Metal (Grade 3) - Gradation	
Sieve Size	Per cent Passing
63 mm	100
53 mm	98
45 mm	71
22.4 mm	7
11.2 mm	4

7.4 Jabalpur Material Sample Results

Table – 28 (a) Physical & Engineering Properties of Iron Ore Mine OB Waste (SGMM)

Property		SGMM (Gulab) Mines	Test Method
Coordinates		23.36296, 80.035304	
Specific gravity		2.95	IS 2720 - Part 3
Liquid Limit (%)		44	IS 2720 - Part 5
Plasticity Index		17	
Gradation	Gravel (%)	20	IS 2720 - Part 4
	Sand (%)	11	
	Silt (%)	58	
	Clay (%)	11	
Standard Proctor Test – γ_d kN/m³ OMC (%)		18.5 16.3	IS 2720 - Part 7
Modified Proctor Test – γ_d kN/m³ OMC (%)		19.3 15.0	IS 2720 - Part 8
CBR (%) At 100% Standard Proctor Density		15	IS 2720 - Part 16
CBR (%) At 98% Modified Proctor Density		–	
Direct Shear Test	Cohesion C (kN/m²)	0	IS 2720 - Part 13
	ϕ	40^0	
Permeability (m/day)		6.5×10^{-3}	IS 2720 - Part 17

Table – 28 (b) Physical & Engineering Properties of Iron Ore Mine OB Waste (Jakhodia)

Property		Jakhodia Mines	Test Method
Coordinates		23.365245, 80.038971	
Specific gravity		2.75	IS 2720 - Part 3
Liquid Limit (%)		39	IS 2720 - Part 5
Plasticity Index		17	
Gradation	Gravel (%)	47	IS 2720 - Part 4
	Sand (%)	28	
	Silt (%)	10	
	Clay (%)	15	
Standard Proctor Test – γ_d kN/m³ OMC (%)		20.0 13.4	IS 2720 - Part 7
Modified Proctor Test – γ_d kN/m³ OMC (%)		21.4 10.0	IS 2720 - Part 8
CBR (%) At 100% Standard Proctor Density		23	IS 2720 - Part 16
CBR (%) At 98% Modified Proctor Density		39	
Direct Shear Test	Cohesion C (kN/m²)	3	IS 2720 - Part 13
	ϕ	43^0	
Permeability (m/day)		10×10^{-3}	IS 2720 - Part 17

Table – 28 (c) Physical & Engineering Properties of Iron Ore Mine OB Waste (Srivastava)

Property		Srivastava Mines	Test Method
Coordinates		23.398009, 80.054228	
Specific gravity		3.05	IS 2720 - Part 3
Liquid Limit (%)		33	IS 2720 - Part 5
Plasticity Index		11	
Gradation	Gravel (%)	51	IS 2720 - Part 4
	Sand (%)	22	
	Silt (%)	19	
	Clay (%)	8	
Standard Proctor Test – γ_d kN/m^3 OMC (%)		22.3 13.5	IS 2720 - Part 7
Modified Proctor Test – γ_d kN/m^3 OMC (%)		2.37 11.2	IS 2720 - Part 8
CBR (%) At 100% Standard Proctor Density		13	IS 2720 - Part 16
CBR (%) At 98% Modified Proctor Density		20	
Direct Shear Test	Cohesion C (kN/m^2)	3	IS 2720 - Part 13
	ϕ	42^0	
Permeability (m/day)		-	IS 2720 - Part 17

Table – 29 Physical & Engineering Properties of River Borne Material (RBM)

Property		RBM	Test Method
Coordinates		23.276437, 79.654484	
Specific gravity		2.61	IS 2720 - Part 3
Liquid Limit (%)		26	IS 2720 - Part 5
Plasticity Index		N.P	
Gradation	Gravel (%)	15	IS 2720 - Part 4
	Sand (%)	75	
	Silt (%)	6	
	Clay (%)	4	
Standard Proctor Test – γ_d kN/m^3 OMC (%)		20.3 11.0	IS 2720 - Part 7
Modified Proctor Test – γ_d kN/m^3 OMC (%)		21.5 7.50	IS 2720 - Part 8
CBR (%) At 100% Standard Proctor Density		31	IS 2720 - Part 16
CBR (%) At 98% Modified Proctor Density		49	
Direct Shear Test	Cohesion C (kN/m^2)	2	IS 2720 - Part 13
	ϕ	38^0	
Permeability (m/day)		86 x 10^{-3}	IS 2720 - Part 17

Table – 30 (a) Physical & Engineering Properties of Hard Shoulder Material (Type 1)

Property		Hard Shoulder Material (1)	Test Method
Coordinates		23.5632, 80.016518	
Specific gravity		3.04	IS 2720 - Part 3
Liquid Limit (%)		42	IS 2720 - Part 5
Plasticity Index		10	
Gradation	Gravel (%)	64	IS 2720 - Part 4
	Sand (%)	20	
	Silt (%)	8	
	Clay (%)	8	
Standard Proctor Test – γ_d kN/m^3 OMC (%)		20.8 14.2	IS 2720 - Part 7
Modified Proctor Test – γ_d kN/m^3 OMC (%)		24.2 7.80	IS 2720 - Part 8
CBR (%) At 100% Standard Proctor Density		8	IS 2720 - Part 16
CBR (%) At 98% Modified Proctor Density		14	
Direct Shear Test	Cohesion C (kN/m^2)	1	IS 2720 - Part 13
	ϕ	30^0	
Permeability (m/day)		5.2×10^{-3}	IS 2720 - Part 17

Hard Shoulder Material Type 1 - Phyllite type rock mixed with soil / Powdered rock

Table – 30 (b) Physical & Engineering Properties of Hard Shoulder Material (Type 2)

Property		Hard Shoulder Material (2)	Test Method
Coordinates		23.5632, 80.016518	
Specific gravity		2.59	IS 2720 - Part 3
Liquid Limit (%)		38	IS 2720 - Part 5
Plasticity Index		21	
Gradation	Gravel (%)	94*	IS 2720 - Part 4
	Sand (%)	2	
	Silt (%)	3	
	Clay (%)	1	
Standard Proctor Test – γ_d kN/m^3 OMC (%)		17.2 17.5	IS 2720 - Part 7
Modified Proctor Test – γ_d kN/m^3 OMC (%)		18.5 13.5	IS 2720 - Part 8
CBR (%) At 100% Standard Proctor Density		12	IS 2720 - Part 16
CBR (%) At 98% Modified Proctor Density		15	
Direct Shear Test	Cohesion C (kN/m^2)	4	IS 2720 - Part 13
	ϕ	29^0	
Permeability (m/day)		0.3×10^{-3}	IS 2720 - Part 17

* - Sample comprised of mixture of Phyllite stone pieces and soil
Hard Shoulder Material Type 2 - Phyllite type rock mixed with very little soil

Table – 31 Physical & Engineering Properties of BC Soil

Property		BC Soil	Test Method
Coordinates		23.364319, 80.054762	
Specific gravity		2.69	IS 2720 - Part 3
Liquid Limit (%)		50	IS 2720 - Part 5
Plasticity Index		26	
Gradation	Gravel (%)	1	IS 2720 - Part 4
	Sand (%)	3	
	Silt (%)	68	
	Clay (%)	28	
Standard Proctor Test – γ_d kN/m^3 OMC (%)		16.3 17.5	IS 2720 - Part 7
Modified Proctor Test – γ_d kN/m^3 OMC (%)		19.5 9.50	IS 2720 - Part 8
CBR (%) At 100% Standard Proctor Density		2	IS 2720 - Part 16
CBR (%) At 98% Modified Proctor Density		4	

Table – 32 (a) Unconfined Compressive Strength of Cement Stabilised Jabalpur RBM Sample

Type of Material		RBM
Coordinates		23.276437, 79.654484
UCS after 3 days curing (MPa)	3% Cement	1.20
	6% Cement	1.70
	9% Cement	1.87
UCS after 7 days curing (MPa)	3% Cement	
	6% Cement	3.10
	9% Cement	3.80
UCS after 14 days curing (MPa)	3% Cement	
	6% Cement	3.30
	9% Cement	4.10

Table – 32 (b) Unconfined Compressive Strength of Cement Stabilised Jabalpur HSM Sample

Type of Material		Hard Shoulder Material Type 1
Coordinates		23.5632, 80.016518
UCS after 3 days curing (MPa)	3% Cement	1.21
	6% Cement	2.25
	9% Cement	2.55
UCS after 7 days curing (MPa)	3% Cement	1.56
	6% Cement	2.51
	9% Cement	3.05
UCS after 14 days curing (MPa)	3% Cement	1.94
	6% Cement	2.84
	9% Cement	3.43

Table – 32 (c) Unconfined Compressive Strength of Cement Stabilised Jabalpur Iron Ore Mine OB Waste

Type of Material		**Jakhodia Mines (Iron ore) OB Waste**
Coordinates		23.365245, 80.038971
UCS after 3 days curing (MPa)	3% Cement	1.13
	6% Cement	1.69
	9% Cement	2.33
UCS after 7 days curing (MPa)	3% Cement	1.42
	6% Cement	2.16
	9% Cement	2.72
UCS after 14 days curing (MPa)	3% Cement	1.71
	6% Cement	2.97
	9% Cement	3.36

Table – 33 Durability Test on Cement Stabilised Jabalpur Samples

Type of Material	Coordinates	Durability (% of UCS Strength - Immersed sample/moist cured sample)		
		3% Cement	6% Cement	9% Cement
Hard Shoulder Material 1	23.5632, 80.016518	23%	40%	77%
Jakhodia Mines OB Waste	23.365245, 80.038971	70%	78%	81%

Table – 34 Properties of Marble Quarry Overburden Rock (Dolomite)

Tests	**Dolomite (Hard Stone) Rock**
Coordinates	23.577282, 80.110073
Specific Gravity	2.83
Water Absorption (After Soaking for 3 days - %)	1.13
Aggregate Impact Value (In Dry State - %)	13.6
Aggregate Impact Value (After Soaking for 3 days - %)	14.4

Table – 35 Properties of Phyllite (Soft Rock)

Tests	**Phyllite (Soft Rock)**
Coordinates	23.5632, 80.016518
Specific Gravity	2.59
Water Absorption (After Soaking for 1 day - %)	21.8
Aggregate Impact Value (In Dry State - %)	63.8

Table – 36 (a) Properties of Local Soil (Data Given by Jabalpur PIU)

NH 7 to Bela (Package 1850) - Coordinates: Lat 23.019090, Long 79.819710	
Properties of Local Soil	
Liquid Limit (%)	59.4
Plastic Limit (%)	32.0
Plasticity Index	27.4
Standard Proctor Test - MDD (kN/m^3)	17.60
Standard Proctor Test - OMC (%)	11.40
Sieve Size	Per cent finer
40 mm	100
25 mm	97
20 mm	93
10 mm	88
4.75 mm	83
2.36 mm	76
1.18 mm	74
600 microns	67
425 microns	63
75 microns	55
Degree of Compaction achieved in the field (%)	100

Table – 36 (b) Properties of Other Conventional Materials (Data Given by Jabalpur PIU)

NH 7 to Bela (Package 1850) - Coordinates: Lat 23.019090, Long 79.819710	
GSB	
Plasticity Index	Non Plastic
Standard Proctor Test - MDD (kN/m^3)	20.89
Standard Proctor Test - OMC (%)	9.0
Degree of Compaction achieved in the field (%)	100.4
CBR (%)	24
Sieve Size	Per cent Finer
26.5 mm	100
4.75 mm	40
75 microns	1.3
WBM Stone Metal (Grade 2) - Gradation	
Sieve Size	Per cent Passing
90 mm	100
63 mm	93
53 mm	55
45 mm	11
22.4 mm	3
WBM Stone metal - AIV (%)	14.96 and 16.91
WBM Stone metal - Flakiness index	19.78
WBM Stone Metal (Grade 3) - Gradation	
Sieve Size	Per cent Passing
63 mm	100
53 mm	96
45 mm	74

22.4 mm	7
11.2 mm	2
Water absorption of stone metal (%)	0.945

Table – 36 (c) Properties of Select Soil (Data Given by Jabalpur PIU)

NH 7 to Khinni (Package 18502) - Coordinates: Lat 23.400544, Long 79.979107	
Properties of Select Soil	
Liquid Limit (%)	35.20
Plasticity Index	17.35
Standard Proctor Test - MDD () and OMC (%)	19.00 kN/m^3 and 12.00%
Sieve Size	Per cent finer
40 mm	100
25 mm	98
20 mm	92
10 mm	88
4.75 mm	85
2.36 mm	82
1.18 mm	75
600 microns	71
425 microns	67
75 microns	61

Table – 36 (d) Properties of Other Conventional Materials (Data Given by Jabalpur PIU)

NH 7 to Khinni (Package 18502) - Coordinates: Lat 23.400544, Long 79.979107	
GSB	
Plasticity Index	Non Plastic
CBR (%)	21
WMM Gradation	
Sieve Size	Per cent Passing
53 mm	100
45 mm	95
22.4 mm	65
11.2 mm	55
4.75 mm	26
2.36 mm	20
600 micron	6
75 micron	0
WMM Stone metal - AIV (%)	12.3

Table – 36 (e) Properties of Local Soil and Other Conventional Materials (Data Given by Jabalpur PIU)

L097 to Madpipariya (Package 1860) - Coordinates: Lat 23.261157, Long 79.650699	
Properties of Local Soil	
Liquid Limit (%)	58.4
Plastic Limit (%)	32.7
Plasticity Index	25.7
Standard Proctor Test - MDD (kN/m^3)	17.30
Standard Proctor Test - OMC (%)	13.20
Sieve Analysis	
Sieve Size	Per cent finer
10 mm	100
4.75 mm	92
2.36 mm	84
1.18 mm	76
600 microns	70
425 microns	67
75 microns	63
CBR of Select Soil (%)	13.75
Degree of Compaction achieved in the field (%)	99.3
GSB	
Plasticity Index	Non Plastic
Standard Proctor Test - MDD (kN/m^3)	20.70
Standard Proctor Test - OMC (%)	9.80
Degree of Compaction achieved in the field (%)	100.86
WBM Stone Metal (Grade 2) - Gradation	
Sieve Size	Per cent Passing
90 mm	100
63 mm	94
53 mm	66
45 mm	10
22.4 mm	3
WBM Stone metal - AIV (%)	10.53
WBM Stone Metal (Grade 3) - Gradation	
Sieve Size	Per cent Passing
63 mm	100
53 mm	96
45 mm	74
22.4 mm	7
11.2 mm	3

8.0 Discussion on Characterisation and Stabilisation Test Results

8.1 Darbhanga District

Darbhanga District is situated towards North of Ganga River. The entire district has alluvial soil plain devoid of any hillocks or stone quarries. Materials available for road construction are river sand, brick bats and soil. The properties of alluvial soil are similar throughout the district. This soil comprises of about 70 - 75 per cent silt, 10 - 15 per cent sand and 15 - 20 per cent clay. The liquid limit is about 25 - 32 per cent and plasticity index is about 10. This soil when compacted to about 100 per cent of standard proctor compaction density has a CBR value of 4 - 5 per cent. But increasing the compaction to about 98 per cent of modified proctor compaction density, raises CBR value to about 6 - 7 per cent. hence improving degree of compaction of subgrade soil / embankment by adopting vibratory rollers can lead to economy in construction cost.

River sand available in the district is very fine grained. This sand in fact comprises of about 49 per cent silt, 9 per cent clay and only 32 per cent sand. Fines content (silt+clay content) is very much above the limits specified for usage of sand in cement concrete. Hence this sand cannot be used for rigid pavement / cement concrete works. However since this sand has significantly higher CBR value, admixing it with locally available soil (by about 50 per cent) and compacting the sand+soil mixture can lead to improvement in subgrade CBR. However, sand must be available within economic leads and proper equipment for pulverising and mixing soil (Tractor towed disc harrow and rotavator) has to be used for mixing. Brickbats available in the district show water absorption of about 13 - 15 per cent. However, there is only very marginal decrease in aggregate impact value (AIV) even after soaking the brickbats in water for 3 days. The AIV of brickbats is well below the limits specified for its use in sub-base layer. Presently, as informed to CRRI team by BRRDA officials, a mixture of brickbats and local river sand (in the ratio 60 per cent brickbats:40 per cent sand) is being used for sub-base construction in many roads. This mix has good CBR value (23 per cent) fulfilling MORD specification requirements.

An attempt was made to stabilise the brickbats and sand mixture by using cement and improve its strength properties. However 7 days unconfined compressive strength (UCS) results showed that cement stabilised mix does not develop specified strength (2.76 MPa) for its use in base course. It can be considered as marginal material and its usage in lower base course can be investigated through test track construction, for roads which would serve as access roads to a single village, i.e., its usage can be attempted for cul-de sac type roads and not for through roads. This is because road construction materials, even for districts located towards North of Ganga River (like Darbhanga) are being transported from Jharkhand, hugely increasing the cost of road construction. This can be reduced by stabilising the locally available material like brickbats and sand, as such or in stabilised form.

8.2 Bhagalpur District

Ganga river flows right across Bhagalpur district. This district too has alluvial soils covering most of its area. The alluvial soil in this district is similar in its properties to soil found in Darbhanga district. It has about 70 per cent silt content and the rest comprises of sand and clay in equal proportions. The CBR value of this soil increased to about 7 per cent (when compacted to 98 per cent of modified proctor compaction test density) as against 5 per cent, when soil is compacted to 100 per cent of standard proctor density. Few hillocks of low height are seen towards southern part of Bhagalpur district. Such hills are seen in adjoining districts also. Tests on stones and moorum available in one such hill showed that they can be a source of good quality stones and moorum. However due to certain environmental and legal reasons such quarries are not presently operating. Good quality stones and sand are being transported from quarries located in Jharkhand which are quite far away.

Kahalgaon thermal power station (KTPS) is located in this district. KTPS uses coal as its fuel. Abundant quantity of pond ash and fly ash are available at KTPS. Pond ash even though fine grained, has a CBR value of 6 - 7 per cent, while fly ash has a CBR value of 2 - 3 per cent only. To study improvement in strength properties of pond ash and fly ash, cement stabilisation was adopted. UCS tests showed that cement stabilised fly ash develops higher strength than cement stabilised pond ash. This can be attributed to chemical reactivity of fly ash which is more than pond ash. About 7 - 8 per cent cement would be required to stabilise the ash for its use in sub-base layer. Such cement stabilised ash samples fulfil the durability test criteria also (minimum 80 per cent strength retention). However, pond ash or fly ash alone do not develop adequate UCS strength for use in base course layer. More over as can be seen from Table 33, neither pond ash nor fly ash fulfil the gradation criteria for cement stabilised material as per MORD Specifications. Hence, it can be considered as a marginal material and test tracks may be constructed to study performance of stabilised ash in sub-base layer. Revised version of IRC SP:72 can be referred to for pavement design using stabilised material.

Table – 33 Comparing Gradation of KTPS ash for Cement Stabilisation

IS Sieve	Per cent by weight passing			
	Cement Stabilised Sub-base	**Cement Stabilised Base**	**Fly ash**	**Pond ash**
53 mm		100	100	100
37.5 mm	95 – 100		100	100
19 mm	45 – 100		100	100
9.5 mm		35 – 100	100	100
4.75 mm		25 – 100	100	100
600 micron	8 – 65		**100**	**100**
300 micron	5 – 40		**99**	**98**
75 micron	0 – 10		**93**	**74**

Cement stabilisation was adopted to test improvement in strength properties of local alluvial soil. It was noticed that local soil also develops adequate UCS for use in sub-base layer. About 7 to 8 per cent cement admixed local soil can be used for sub-base construction.

8.3 Gwalior District

Gwalior district in Madhya Pradesh state has plateau area (Bundelkhand plateau) and few hills (highlands). Rainfall is comparatively less. The soil in the plateau region is clayey type Black Cotton (BC) soil. The hillocks have many types of stones and district has several iron ore mines. Due to mining and quarrying activities, abundant quantity of mine over burden (OB) waste is available. These are now being dumped by the side of such mines. Such OB dumps are not only environmental and aesthetic scourge, they also lead to wastage of valuable land. Very good quality basalt / dolomite quarries are seen at Bilaua and Nayagaon. While good quality hard stones are being crushed and sold, weathered weak rock is often mixed with gravelly soil OB material and dumped adjacent to quarries. Such material was collected from two different stone quarries at Bilaua and Nayagaon, and it was characterised. It was observed that the mix of OB soil + stone chips comprise mainly of coarse grained material (gravel + sand). Accordingly, such material has very good CBR value even at 100 per cent standard proctor compaction test density. The CBR value increases by about one third when the material is compacted to 98 per cent of modified proctor compaction density.

In a similar manner, iron ore mine OB waste collected from Panihar village, also comprises mainly of gravel + sand particles. Its CBR value is also very high (25 per cent at 100 per cent standard proctor compaction density), which increases only marginally after compacting it to a higher density.

Cement stabilisation technique was adopted to check whether such stabilised material fulfils criteria for its use in base / sub-base course. It was noticed that, with about 6 per cent cement addition, both stone quarry waste and iron ore mine waste, develop very good strength in excess of specified UCS requirement (2.76 MPa at 7 days). Further such cement stabilised material complies with durability test criteria also. Hence cement stabilised mine waste / OB material can be adopted in road works even for base course also.

Flaky type of sand stones available near Nayagaon have adequate strength (AIV) but they may be having higher flakiness index (FI) after crushing. Such type of aggregates can also be used in lower base course and test track studies can be initiated.

8.4 Jabalpur District

Jabalpur district has plain lands with some hills (highlands). The soil type comprises of Black Cotton (BC) soil in the plains and hilly areas have red / gravelly type of soil. Similar to Gwalior district, Jabalpur also has Basalt/ Dolomite quarries where premium grade good quality hard crushed stone aggregates is manufactured. This district has several iron ore, blue dust, china clay and marble mines also. Open cast mining is generally practiced which results in generation of huge quantities of over burden (OB) waste. Narmada and other rivers flow across Jabalpur district and bring River Borne Material (RBM - Gravel mixed with sand) and good quality sand. The annual rainfall in the district is in excess of 1000 mm and hence considerable area of district is forested land. From environmental point as well as from economic point, it would be prudent to use OB waste from different quarries in road works.

Iron ore mine OB waste from three different mines was characterised to explore its feasibility. The iron ore mine OB waste OB material mainly comprise of soft rocks like Phyllite and Laterite, and strength properties of OB material is determined by properties of such rocks. It can be seen from Tables 25 (a), 25 (b) and 25 (c) that properties of OB material from different mines varies widely. The composition of OB waste has gravel and sand as major constituents. However liquid limit may exceed 35 per cent specified for usage in sub-base course. CBR of iron ore mine OB waste shows marked improvement when such material is compacted to a higher density.

RBM has sand as its major component and has about 10 per cent fines and 15 per cent gravel. Hence this material has very good CBR even at 100 per cent standard proctor compaction density, compacting it to a higher density (98 per cent of modified proctor compaction density) increases CBR value to almost 50 per cent making it suitable for use in lower base course from strength point. However as shown in Table 34, gradation of RBM does not fit exactly into any of the MORD specified gradations for sub-base material. Hence it can be considered as a marginal material and test track studies can be initiated to use it as such (or after improving its gradation) in sub-base / base courses.

Table – 34 Comparing Gradation of RBM (Jabalpur) MORD Specifications for Sub-base

Sieve Size	RBM Gradation	Gradation Range Specified as per MORD		
		GSB Gr III	Gravel Sub-base	Soil – Aggregate Sub-Base
19.5 mm	100	100	80 – 100	100
9.5 mm	97		55 – 80	80 – 100
4.75 mm	**85**	25 – 45	40 – 60	50 – 75
2.36 mm	**66**	–		35 – 60
600 micron	22			15 – 35
425 micron	18	–	15 – 30	
75 micron	10	< 15	< 15	< 15

Hard shoulder material (HSM) comprises mainly Phyllite rocks (which is very soft) mixed with soil. Hence this material has considerably less CBR value. BC soil found in this district has typical characteristics of clayey soil. It has liquid limit of 50 per cent and CBR of 2 per cent (when compacted to 100 per cent of standard proctor compaction test density) making it a poor quality fill material.

To study improvement in strength properties, RBM, HSM and iron ore mine OB waste were stabilised using cement and UCS tests were conducted. From Tables 29 (a), (b) and (c), it can be seen that, UCS of cement stabilised RBM and HSM 1 is quite high and they fulfil criteria for use even in base course layer (MORD Specification - 7 days UCS of 2.76 MPa (Minimum). However, durability test results are not very good for cement stabilised HSM 1, and cement requirement would have to be decided based on durability criteria rather than UCS. From Table 35, it can be seen that these materials fulfil gradation and plasticity requirements for cement stabilisation, except HSM 2. It may be mentioned here that the hard shoulder material samples collected, comprised of two varieties, HSM 1 in which powdered material / soil proportion was substantially higher and HSM 2 which comprised mainly soft rock pieces with a small percentage of fines. HSM 1 is more suitable for cement stabilisation work.

Table – 35 Comparing Gradation & Plasticity Properties of Jabalpur Samples with MORD Specifications for Cement Stabilised Base/Sub Base

IS Sieve	% By Weight Passing	Type of Material				
Specified Gradation for Cement Stabilised Sub Base		River Borne Material (RBM)	Hard Shoulder Material (HSM 1)	Iron Ore Mine OB Waste - Jakhodia	Iron Ore Mine OB Waste - SGMM	Hard Shoulder Material (HSM 2)
Coordinates		23.276437, 79.654484	23.5632, 80.016518	23.365245, 80.038971	23.36296, 80.035304	23.5632, 80.016518
37.5 mm	95 -100	100	**82**	100	100	**29**
19 mm	45 -100	100	74	98	92	**8**
600 micron	8 - 65	22	17	29	**73**	**5**
300 micron	5 - 40	14	17	26	**71**	5
75 micron	0 - 10	10	**16**	**25**	**69**	4
Specified Gradation for Cemented Base						
53 mm	100	100	91	100	100	45
9.5 mm	35 - 100	97	61	79	85	7
4.75 mm	25 - 100	85	47	53	80	6
Liquid Limit (LL) and Plasticity Index (PI) criteria						
LL < 45 %		26%	42%	39%	44%	38%
PI < 20		NP	10	17	17	**21**

Cement stabilised iron ore mine waste also shows substantial UCS values, which makes it fit to be used even for base course. However, percentage of cement required would be slightly higher than RBM or HSM 1. As can be seen from Table 35, iron ore mine waste comprises of higher quantity of fines than limits specified for sub-base course.

Marble quarry OB material mainly comprised of very good quality dolomite rocks (Photo 6). Strength properties of this material make it fit for use as premium grade stone aggregates. Crushing and sizing of these rocks stacked by the side of marble quarries is required. As informed to CRRI team, marble processing (cutting, slicing and polishing) is not being done on a wider scale at many marble quarries. As a result, marble slurry dust (MSD) is not available in large quantities.

9.0 GIS Methods to Store/Retrieve Construction Material Data-Base

In order to utilise the marginal/ locally available materials in lieu of conventional road construction materials, it is essential to have a compiled data-base of such materials available in different parts of the country, which would help the authorities to explore the possibilities of their usage in different layers of road pavement. It is important to identify the locally available/marginal materials with their geographical locations. Geographical locations can be identified by using latitude and longitudes (coordinates) of the place of their availability. It is also required to characterise such materials to find their physical and engineering properties. Such data on locally available / marginal materials, if available district wise, would boost utilisation of locally available / marginal materials in road construction.

Now the question arises as to how and where this information should be stored so that concerned persons/officials and contractors and Departments can utilise in the best possible manner. Moreover, such information needs to be updated, whenever required. Conventional methods (Static methods) to make hard copy and store and retrieve are very difficult task. Such hard copies may be difficult to interpret and project relationship between land-use features with static data shown on the map. Therefore, a dynamic system is required for this purpose, which should be the free form all the shortcoming of conventional method. NRRDA authorities and CRRI scientists decided that such data should be stored in a user friendly intelligent Geographical Information System (GIS) platform in the form of different layers of sets of data pertaining to locally available/ marginal / conventional road construction materials viz., location (coordinates - latitude and longitude), physical and engineering properties, photos and other related information such as road network, soil map, elevations, etc for best use and easy interpretation of stored data.

9.1 Preparation of Data-base in GIS

GIS is a computer system capable of assembling, storing, analysing, and displaying geographically referenced information, i.e. data identified according to their locations. GIS data can be stored with reference to point (location), line or polygons. GIS data is mainly of two types 1) Raster – Grid data viz. Satellite Images, scanned maps, etc. 2) Vector – Linear viz. Points, lines & polygons, Features such as habitations, lake, etc. and Attributes such as size, type, length, etc. All such information is stored with reference to latitude and longitude so that vector data can be seamlessly joined with raster data.

9.2 Application of GIS in the present study

Applications of GIS are virtually endless. It has enormous capabilities and has applications in every field. Some of the advantages of using GIS in this project are listed below:

i. Data will be in the soft form at their geographical locations to eliminate the storage problem.
ii. Any amount of data can be stored and can be accessed from any part of India.
iii. It can be updated any time and from anywhere, easily modifiable and has better presentation
iv. Easily assessable in the desirable format for users as the maps are dynamic in nature.
v. Restricting access to data based on user requirement is possible
vi. It can analyse to answer user queries depending upon the data and its structure
vii. It is environmental friendly since paper usage is minimised. Many soft copies can be made for any number of users.

The present study has been taken up in four districts - Bhagalpur and Darbhanga in Bihar and Jabalpur and Gwalior in Madhya Pradesh. Accordingly GIS database has been designed to provide information about properties of road construction including locally available/ marginal materials in the referred districts. TNTMips GIS software available at CRRI has been used to prepare this GIS data-base. The system is user friendly and relevant information has been stored in different layers along with geographical locations and other road related information for that district. Information regarding any other construction materials from these four study districts can be added to this GIS platform subsequently. Though initially only four districts have been taken as a pilot study, this system can be extended country wide and the model prepared serves as an example for the management perspective.

9.3 Data sources

Sources of spatial data include paper maps, charts, and drawings scanned or digitised images, digital files imported from CAD graphics systems, coordinate data recorded using a GPS receiver and data captured from Google maps. Attribute data such as demographic details, road inventory, etc. have been obtained from various secondary sources such as Census records, statistical handbooks, data obtained from Rural Works department, etc. The road network information has been obtained from BRRDA and MPRRDA sources. District soil maps, minerals, elevations, etc have been obtained from maps published by Government of India. Following were the broad steps for preparing data-base in the GIS platform in this study:

i. Preparation tracings with the help of Topo-sheets showing spatial data and Control points
ii. Scanning the tracing in jpg format
iii. Selecting the projection system
iv. Registering the raster image in GIS Software (TNTMips) using sufficient number of control points
v. Converting the map to vector image through digitisation in point, line and area layer

vi. Creation of various layers of data - Boundary (state, district, block boundaries), road network (NH, SH and rural roads in the study districts), water bodies, construction material (conventional and locally available / marginal) properties including stabilisation data, soil and rock maps for the district, important towns, village locations, etc. A typical boundary layer created for Bhagalpur District is shown in Fig 1.

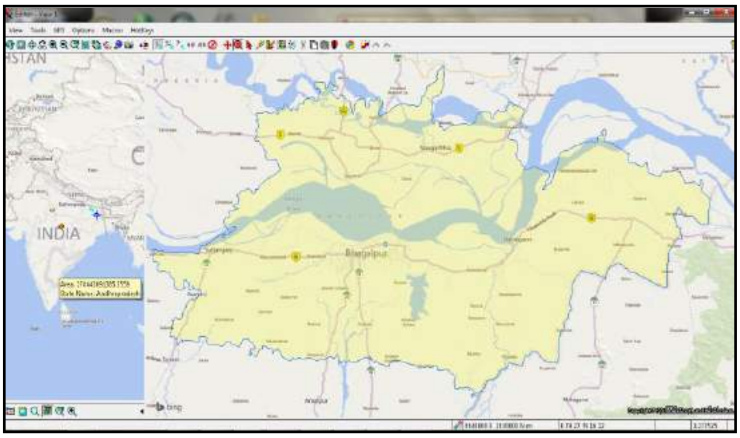

Fig - 1 Boundary Map (Layer) for Bhagalpur District

vii. Attaching the attribute data to the various layers of the map

viii. Preparing queries and thematic maps to analyse the data and make it user

ix. Atlas creation - TNTatlas is a freely available product for viewing hierarchical atlases prepared in TNTmips. Using this software, GIS data generated layer wise for the four districts may be shared with other remote centres. Any user can access read only data (images, material property data, locations, road network, water bodies, etc) embedded in the GIS platform using the freely available TNTatlas.

10.0 Conclusions and Recommendations

The present study eventhough taken up in only four districts as a pilot project, has shown several important findings as given below. Implementation of such findings can lead to construction of construction of economical and environmentally friendly roads, conservation of good quality construction materials, and reduction in carbon foot print.

1. Many types of locally available / marginal materials like mining and quarrying wastes (over burden material, low grade ore which is not useful for metal extraction, weathered rock, moorum, etc), industrial wastes (fly ash, slag, etc), flaky or soft aggregates (laterites, phyllites, shales, brickbats, slate, etc), excavation / tunnelling or river dredging material (rock powder, rock pieces, fine sand, gravel) from other infrastructure projects are available in different parts of the country. Using such materials in road works would be a 'win-win' situation for all concerned - road construction

agencies would get construction materials at lower cost, mining agencies and industries would be able to dispose unwanted by-products (which they consider as 'Waste') and save precious land and public will be benefitted through construction of economical and environment friendly roads.

2. Road construction materials are required to comply specification requirements with regard to gradation, plasticity and strength / density criteria. Locally available / marginal materials may not have all the attributes of conventional good quality road construction materials and hence they may not satisfy one or more specification requirements for usage in a particular layer. To promote usage of locally available / marginal materials, firstly it is required to prepare a nationwide data-base of geographical availability (location defined by coordinates) and physical and engineering properties of such materials (properties of materials as available and also after stabilisation to improve its properties). Test track construction and monitoring are required as next step to establish their field performance.
3. Strength properties of locally available / marginal materials can be improved in many cases by enhancing compaction standards. Adoption of modified proctor compaction test and use of vibratory rollers can be incorporated in specifications and contract documents, especially when such materials are planned to be used in road works.
4. Stabilisation techniques - mechanical as well as chemical admixture stabilisation can be judiciously adopted to enhance strength properties of locally available / marginal materials. Portland cement which is available everywhere can be used for admixture stabilisation in most of the cases. While using stabilised material in subgrade / sub-base can be achieved even when strength improvement is lower, use of stabilised material in base course would rely upon adequate strength gain, which in turn depends on quantum of coarse aggregate size particles and cement percentage in the mix. The present revision of IRC SP:72 has design templates for road pavement cross section using stabilised base / sub-base, which can be referred to. Test track studies would be essential to establish feasibility of usage of stabilised marginal / locally available materials in different layers of road pavement.
5. Producers of locally available / marginal materials (like mine / quarry owners) need to be educated and sensitised about proper mode of disposing such materials. Non plastic, predominantly rock based over burden material/ low grade ore should not be mixed with soil and dumped. Such a process would render even a useful material as 'waste'. The by-product material (OB waste / low grade not useful ore / tunnelling muck / dredged material, etc) would have to be collected and stored carefully by agencies who produce them, so that optimal use of such materials becomes possible. Unscientific disposal / mixing with soil may make a material useful for sub-base or subgrade only, which could otherwise have been used in base course.

6. It is very important and essential to characterise such materials from environmental safety / acceptability point also (heavy metal content, leachate analysis, etc). Eventhough wastes like fly ash have been classified as 'Non hazardous' by environmental regulatory bodies, same cannot be applied for all other mining / industrial wastes. All such materials would have to be characterised to establish their 'Non hazardous and safe for use in road works' aspect. The present study by CRRI is limited only to establish their engineering feasibility.
7. The availability and nature / properties of such locally available / marginal materials varies widely over India. While characterising such materials, it is pertinent to note that their properties do not follow a pattern similar to conventional good quality road construction materials. For example, fly ash may be non plastic but it usually has higher OMC, while naturally occurring non plastic soils tend to have lower OMC. Hence, efforts can be initiated to formulate specifications applicable to particular states to promote usage of locally available materials.
8. This study can be extended to all other states / districts in India. STAs can be entrusted with this task and CRRI can coordinate / guide STAs in this endeavour. For extending this study, each state can be divided into 'Regions' which are similar rather than taking up the study district wise. Districts which have similar types of soil, materials, climate, industrial activities and are adjoining can be clubbed to represent a region. For example, Darbhanga and other surrounding districts have many similarities with regard to soil and material availability and they can be clubbed to form a 'region'. The availability of marginal and conventional materials would be similar in such a region with few exceptions like thermal power plants/ steel plants, etc which may not be located in every district of that region.
9. Special training programmes would have to be arranged for PIU officials/ engineers to educate them about stabilisation techniques, use of locally available / marginal materials, etc. Producers of such materials can be made partners by road construction agencies for organising such training programmes. Efforts can be made to partner them to bear a fraction of transportation cost of such materials also.