Use of Marginal Materials & Fly ash in Road Works

U.K. Guru Vittal
Sr. Principal Scientist
Central Road Research Institute
New Delhi – 110 025
vittal.crri@gmail.com
Introduction

- **Issue** – Development Vs. Environment
- **Aggregate Demand for Roads** – 300 million tons/year
- Need to harness marginal materials
- **Rural Roads** – Less than 200 vehicles per day
Marginal Material

- ‘Any material not wholly in accordance with the specification in use in a country or region for normal road materials but can be used successfully either in special conditions, made possible because of climatic characteristics or recent progress in road techniques or after subjecting to particular treatment’

  From: PIARC

- ‘Aggregate produced from a weathered or weathering prone rock, which after processing contains moderate to high plastic fines, is susceptible to weathering and when compacted has soaked CBR value between 40 to 100%’

  Brennan, 1984
Marginal Material

Moorum

Gravels

Brickbats

Shale

Laterite
Types of Marginal Materials

- **Group I: Hard Rocks** – Foliated metamorphic rocks that do not meet the requirements of a crushed stone base.
- **Group II: Weak rocks** – Conglomerates, shales (weakly cemented, poorly consolidated, partially weathered rocks)
- **Group III: Natural Gravels** – Transported and residual soils/gravels
- **Group IV: Duricrusts** – Indurated or partially indurated soils
- **Group V: Manufactured materials** – Man made materials like fly ash, slag, C&D waste, etc

From: J R Cook and C S Gourley
Why Use Marginal Materials?

- Road construction material selection – *Fitness for purpose*
- *Neither sub-standard nor wastefully above the standards demanded by their engineering task*
- *Wide range of low grade materials used successfully*
  - Traffic is low
  - Environment understood and accounted
  - QC is adequate
  - Maintenance is timely

From: Cook J R, Bishop E C, Elsworth N E, TRL
Present Guidelines on Locally Available Materials

- Selected granular soil for subgrade
- Stabilisation of local soil
- Brick and over burnt brick metal
- Industrial wastes
- Stone metal
- Naturally occurring softer aggregates like Kankar, Moorum

<table>
<thead>
<tr>
<th>Material Occurrence State</th>
<th>Manner of Using</th>
<th>Test/ Quality Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blocks or large discrete particles</td>
<td>As WBM without screenings/ filler</td>
<td>Wet AIV not to exceed 50, 40 or 30</td>
</tr>
<tr>
<td>Graded form without much soil</td>
<td>As GSB layer or for base/ surfacing</td>
<td>PI &lt; 6 base/ sub-base, 4 – 10 for surfacing</td>
</tr>
<tr>
<td>Discrete particles mixed with soil</td>
<td>Soil-Gravel mix: sub-base, base/ surfacing</td>
<td>CBR and PI criteria and Well graded</td>
</tr>
</tbody>
</table>

IRC SP:72, Clause 5.2
Present Guidelines for Marginal Materials

- Specifications – Gradation, Plasticity and Shear Strength
- Required to meet specification thresholds
  - Passing 75 micron sieve to be less than 8 per cent
  - PI to be less than 6
  - CBR to be 80 per cent
- Material Specifications for high traffic density NH/ SH are similar to low traffic volume rural roads
- No difference between conventional and marginal material – Specification requirements are same
- Materials specifications do not consider rainfall or traffic or type of material available
Unbound Sub-Base/ Base (AASHTO)

<table>
<thead>
<tr>
<th>Sieve size</th>
<th>Per cent by weight passing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td>50 mm</td>
<td>100</td>
</tr>
<tr>
<td>25 mm</td>
<td>–</td>
</tr>
<tr>
<td>9.5 mm</td>
<td>30 – 60</td>
</tr>
<tr>
<td>4.75 mm</td>
<td>25 – 55</td>
</tr>
<tr>
<td>2 mm</td>
<td>15 – 40</td>
</tr>
<tr>
<td>425 micron</td>
<td>8 – 20</td>
</tr>
<tr>
<td>75 micron</td>
<td>2 – 8</td>
</tr>
</tbody>
</table>

- LL < 25, PI < 6; Los Angeles wear < 50%
- ASTM Gradation for sub-base 75 μm sieve 0 – 12%, 4.75 mm 30 – 60%

AASHTO M 147-65, 1980  
ASTM D 2940
Unbound Sub-Base/ Base (U.K)

- Plasticity characteristics

<table>
<thead>
<tr>
<th>Climate</th>
<th>Liquid Limit</th>
<th>PI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moist tropical and wet tropical</td>
<td>&lt; 35</td>
<td>&lt; 6</td>
</tr>
<tr>
<td>Seasonally wet tropical</td>
<td>&lt; 45</td>
<td>&lt; 12</td>
</tr>
<tr>
<td>Arid and semi-arid</td>
<td>&lt; 55</td>
<td>&lt; 20</td>
</tr>
</tbody>
</table>

- Gradation – Natural road gravel

<table>
<thead>
<tr>
<th>Sieve size</th>
<th>Per cent by weight passing BS sieve</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>37.5 mm</td>
</tr>
<tr>
<td>50 mm</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Close graded material</td>
</tr>
<tr>
<td>10 mm</td>
<td>45 – 65</td>
</tr>
<tr>
<td>425 micron</td>
<td>10 – 25</td>
</tr>
<tr>
<td>75 micron</td>
<td>5 – 15</td>
</tr>
</tbody>
</table>

From: Road Note 31, TRL
Unbound Sub-Base/ Base (Thailand)

- **Base Course**
  - Liquid limit < 25, PI < 6 *(Proposed: LL < 28, PI < 10)*
  - Los Angeles abrasion < 40 per cent *(Proposed: LAA < 50)*
  - Soaked CBR > 80 per cent

- **Sub-base Course**
  - Liquid limit < 35, PI < 11 *(Proposed: LL < 38, PI < 15)*
  - Los Angeles abrasion < 60 per cent
  - Soaked CBR > 25 or 30 per cent *(Proposed: CBR > 15)*

- Gradation similar to AASHTO specification (A to E), *(Proposed: Passing 75 μ sieve < 25 %)*

From: Teeracharti Ruenkraitergsa, Dept of Highways, Thailand
## Unbound Sub-Base/ Base (Brazil)

### Base Course

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Traffic Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Heavy</td>
</tr>
<tr>
<td>CBR (%)</td>
<td>≥ 80</td>
</tr>
<tr>
<td>Liquid Limit (%)</td>
<td>&lt; 35</td>
</tr>
<tr>
<td>Plasticity Index</td>
<td>&lt; 10</td>
</tr>
<tr>
<td>Los Angeles abrasion (%)</td>
<td>&lt; 65</td>
</tr>
<tr>
<td>Swell from CBR Test (%)</td>
<td>&lt; 0.2</td>
</tr>
</tbody>
</table>

### Sub-base Course – Similar to above table except CBR ≥ 20

### Gradation to conform to AASHTO specification, except Grades E and F are not used

From: Departamento National de Estradas de Rodagem, Brazil
Unbound Sub-Base/ Base (South Africa)

- PI < 13 to < 20 specified based on rainfall
- Gradation – Natural road gravel

<table>
<thead>
<tr>
<th>Sieve size</th>
<th>Per cent by weight passing BS sieve</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>37.5 mm</td>
</tr>
<tr>
<td>50 mm</td>
<td>100</td>
</tr>
<tr>
<td><strong>Close graded material</strong></td>
<td></td>
</tr>
<tr>
<td>10 mm</td>
<td>40 – 80</td>
</tr>
<tr>
<td>425 micron</td>
<td>8 – 30</td>
</tr>
<tr>
<td>75 micron</td>
<td>5 – 20</td>
</tr>
</tbody>
</table>

- In Kenya, PI < 15 (wet areas) < 20 (dry areas), CBR > 30%

From: Gourley & Greening, 1999
Way Forward

- Need to collect and analyse information on international practices and norms on use of marginal materials
- Understanding marginal materials available in our country and their engineering properties in a better way
- Preparation of realistic design and construction guidelines on marginal material usage for road works
- To adequately consider issues like traffic, rainfall, water logging, availability of materials, etc in the guidelines
- R&D work on usage of such materials, field demonstration projects, collection of performance data etc.
Fly Ash for Road Embankment

Typical cross section of fly ash road embankment
Fly Ash for Pavement Construction

- Stabilised soil subgrade & sub-base/base courses
  - Mixing with soil reduces plasticity characteristics of subgrade
  - Addition of small percentage of lime or cement greatly improves strength
  - Leaching of lime is inhibited and durability improves due to addition of fly ash
  - Pond ash & bottom ash can also be stabilised
  - Lime-fly ash mixture is better alternative to moorum for construction of WBM / WMM
Effect of Fly Ash Usage in Concrete

- Replacement of cement – Mix to be redesigned based on improvement in workability
- Concrete becomes more impervious
- Increase in durability, sulphate resistance and reduction in alkali-aggregate reaction even in chemically aggressive environment
- Usage is economical and environment friendly
- Grade 43 and 53 have higher proportion of C$_3$S and low amount of C$_2$S, high initial strength is ensured but quantity of free lime leached is more, hence fly ash usage is a must
Roller Compacted Concrete

- Zero slump concrete which is compacted using a road roller
- Lower water cement ratio results in higher strength than similar blends of conventional concrete
- Possesses advantages like faster rate of construction, lower cost, elimination of expansion joints, increased joint spacing, etc
- Most importantly fly ash can be used to replace 30 to 50 per cent of cement
Typical Cross Section of Rural Road - Conventional Section & Using Fly ash
Demonstration Road Project Using Fly Ash Near Dadri (U.P) - Typical Section

- RCCP wearing course - 0.1 m
- Stabilised fly ash base - 0.1 m
- Soil cover - 0.3 m thick
- Bottom ash
- Stabilised fly ash Shoulder
Demonstration Road Project Using Fly Ash Near Dadri (U.P.)

Stabilised base course

Mixing & laying of RCCP

Mixing of RCCP
Construction of Rural Roads Using Fly Ash at Dandeli, Karnataka

Mixing of fly ash with cement

Spreading of cement mixed fly ash
Construction of Rural Roads Using Fly Ash at Dandeli, Karnataka

Compaction of stabilised fly ash

A view of compacted fly ash layer
APTF Studies on Fly ash Usage
CRRI Studies on Use of Fly ash

Raichur

Dadri

Dandeli

Dandeli
APTF Studies on Fly ash Usage

- IRC recommends using cemented base/ sub-base
- Bound base/ sub-bases crack thereby reducing strength
- Very limited data available on field performance of bound base / sub-base
- Proposed study focuses on Use of Fly ash in cemented base / sub-base using APTF

The Proposal under active consideration of DST, Government of India
Support from NRRDA / MORD requested please
Thank you
vittal.crri@gmail.com