Sustainable Alternative Industrial Waste Materials for Infrastructure Development

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- Acknowledgements to my former colleagues and project co-workers for guidance, knowledge exchange, work inputs, etc.

- Best wishes to juniors who are carrying forward this R&D work at the Institute

Utilisation of Fly Ash in Road Works

- Present production about 150 million tons/ annum
- 175 thermal power plants in the country
- About 80% of ash produced is used.
- PPC production consumes about 25% of ash
- Road works utilise about 20% of ash production

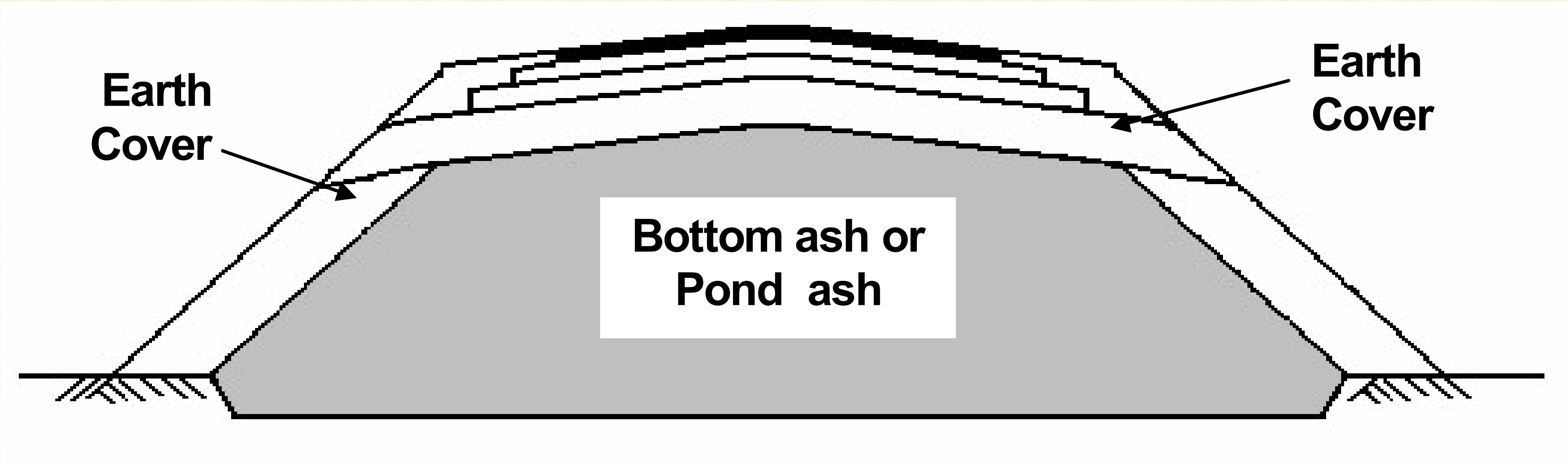
Utilisation of Fly Ash in Road Works

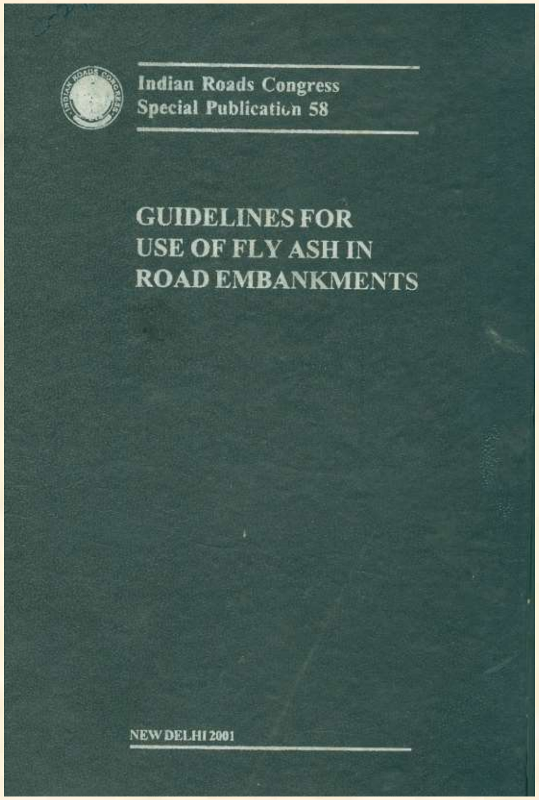
- Can be used for construction of
  - Embankments and backfills – Reinforced or unreinforced
  - Stabilisation of subgrade, sub-base and base course
  - Rigid pavements, paving blocks, kerb stones
- Fly ash properties vary, to be characterised before use
- Major constituents – oxides of silica, aluminum, iron, calcium & magnesium
- Environmentally safe material for road works
- Many favourable properties for embankment & road construction – Light weight (ideal over weak subsoil), higher shear strength (greater stability), no lumps, usually moist, compacted under inclement weather, cost savings, etc

Engineering Properties of Fly Ash & Soil

Parameter	Fly ash	Sand	Silt	Clay
Specific gravity	1.90 – 2.55	2.65 – 2.70		
Plasticity index	NP	NP	NP – 17	> 17
Compaction test- MDD (kN/m^3)	9.0 – 16.0	17.5– 18.4	15.2 – 20.0	14.5 – 18.0
Optimum moisture content (%)	38.0 – 18.0	15.0 – 9.0	18.0 – 10.0	30.0 – 15.0
Angle of internal friction (ϕ)	$30^0 – 40^0$	$28^0 – 45^0$	$25^0 – 35^0$	$0^0 – 10^0$
Cohesion (kN/m^2)	Negligible	0	10 – 25	30 – 60
Compression index	0.05 – 0.4	–	0.05 – 0.15	0.30 – 2.60
Permeability (cm/sec)	$10^{-3} – 10^{-5}$	$10^{-2} – 10^{-4}$	$10^{-5} – 10^{-7}$	10^{-7} or Less
Particle size distribution Clay size fraction (%) Silt size fraction (%) Sand size fraction (%) Gravel size fraction (%)	 1 – 10 8 – 85 7 – 90 0 – 10	4.75 – 0.075 mm	0.075 – 0.002 mm	Less than 0.002 mm

Typical Cross Section of Fly Ash Road Embankment





Guidelines for Use of Fly Ash in Road Embankments (IRC SP:58)

Fly ash Embankment at Wazirabad

- Construction of approach embankment for Wazirabad Signature Bridge at Delhi – Fly ash used as fill material in waterlogged area
- Huge savings in construction cost due to usage of fly ash instead of granular material in waterlogged area
- Reinforced earth wall of 6 m height constructed over 10.3 m high unreinforced fly ash embankment

Construction of Embankment





Environmental Acceptability

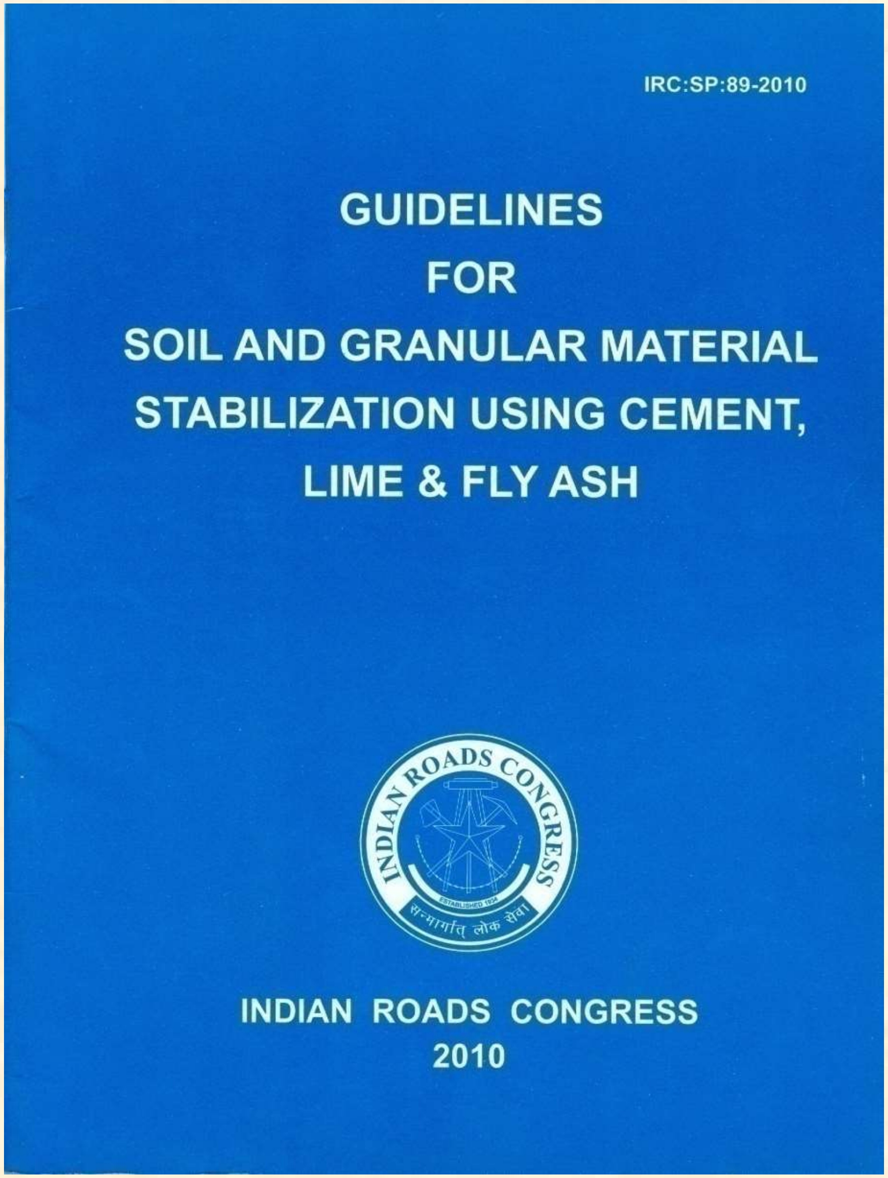
Contaminant (mg/kg) ppm	BTPS Pond ash	Rajghat Pond ash (No. 1)	Rajghat Pond ash (No. 2)	River bed Soil sample (No. 1)	River bed Soil sample (No. 2)	Limits as specified for Hazardous Materials by MOEF, GOI
Copper	23	43	83	40	23	5000
Cadmium	01	BDL	01	01	01	50
Chromium	55	113	76	115	55	50
Zinc	104	105	98	102	80	20,000
Lead	14	24	80	20	16	5000

BDL (Below Detection Level) – 1 mg/kg

Reinforced Fly Ash Embankment

- Use of reinforcement in backfill material to improve its strength – Reinforced embankment
- Composite material
  - Facing panels
  - Reinforcement
  - Selected back fill material
- Friction between backfill and reinforcement
- Application
  - Reinforced earth wall
  - Improving bearing capacity
- Fly ash – better backfill material for reinforced embankments

Fly ash Stabilisation



Guidelines for Soil and Granular Material Stabilisation Using Cement, Lime & Fly ash (IRC SP:89)

Using Waste Plastic in Bituminous Layer

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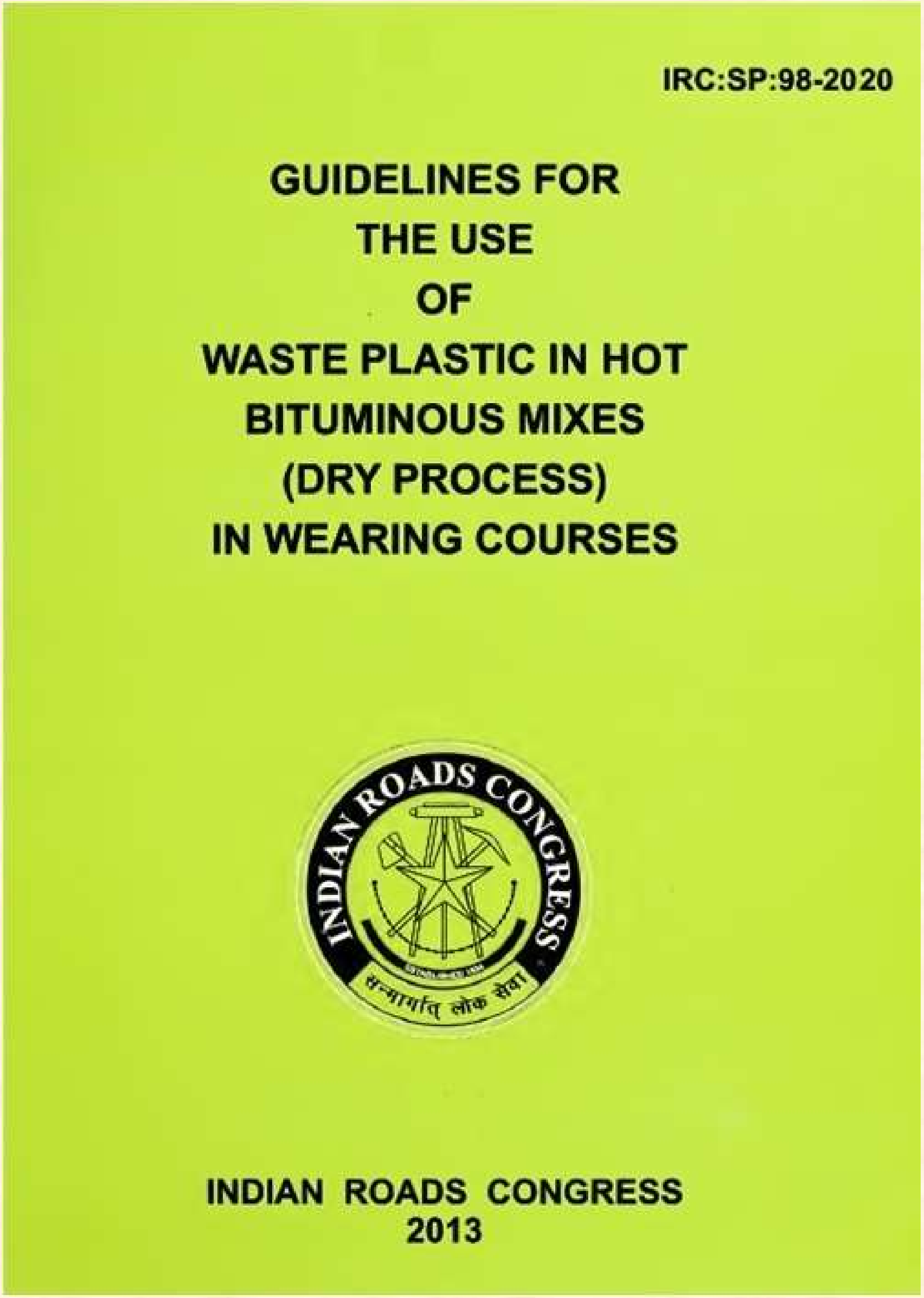


Waste Plastics Usage

- **Dry Process** – Coating waste plastic over preheated hot aggregates, before mixing it with bitumen, IRC SP:98
- **Wet Process** – When waste plastic is mixed with hot molten bitumen, patented process
- Improves property of aggregates, temperature required is same as mixing temperature (140 to 165^{0}C)
- **Size of waste plastic** – Passing 2.36 mm sieve and retained on 600 micron sieve
- **Dust and impurities** in waste plastic **not to exceed 1%**
- Care to be taken to ensure **aggregate temperature does not exceed 180^{0}C**, Otherwise harmful gases may be released
- Coated aggregates mixed with '**Paving Grade Bitumen**'

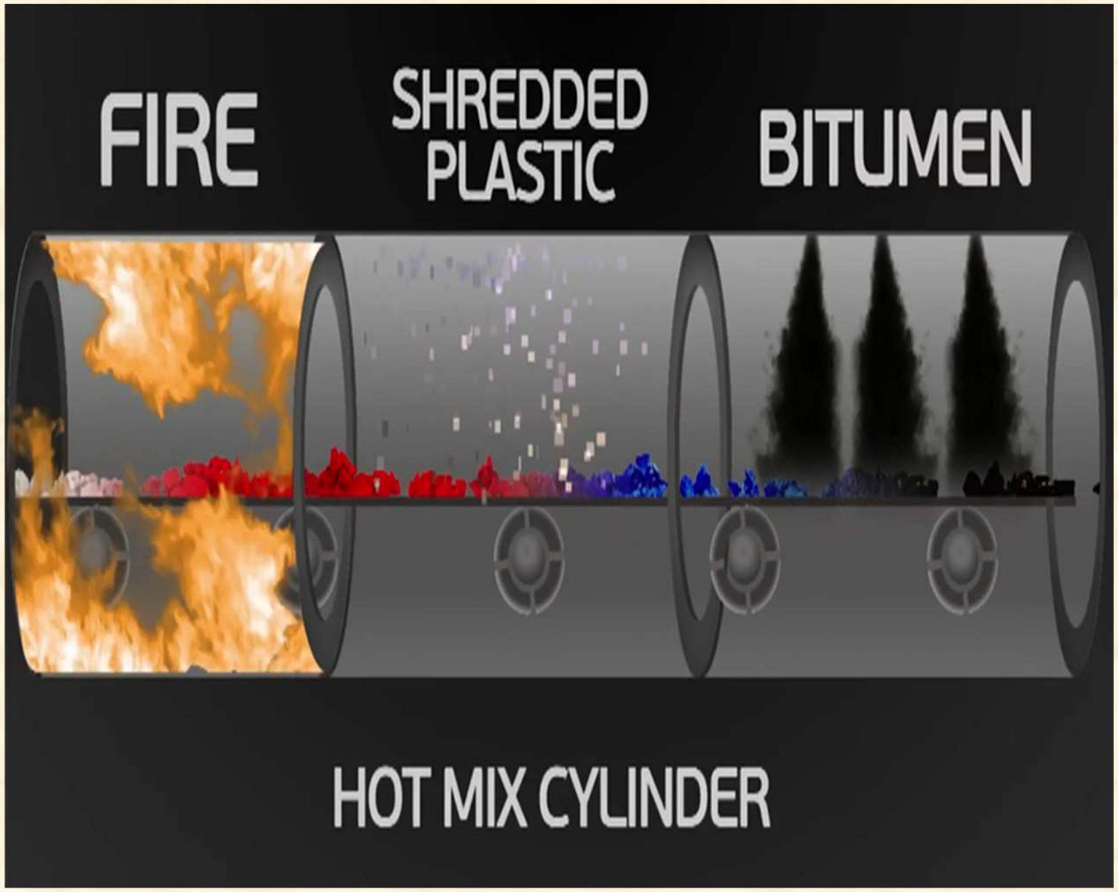
Process Details

- **Collection of waste plastic** – Garbage trucks, rag pickers, NGOs, waste buyers, school children, etc
- **Cleaning and shredding of waste plastic** – De-dusted, washed if necessary

Process Details

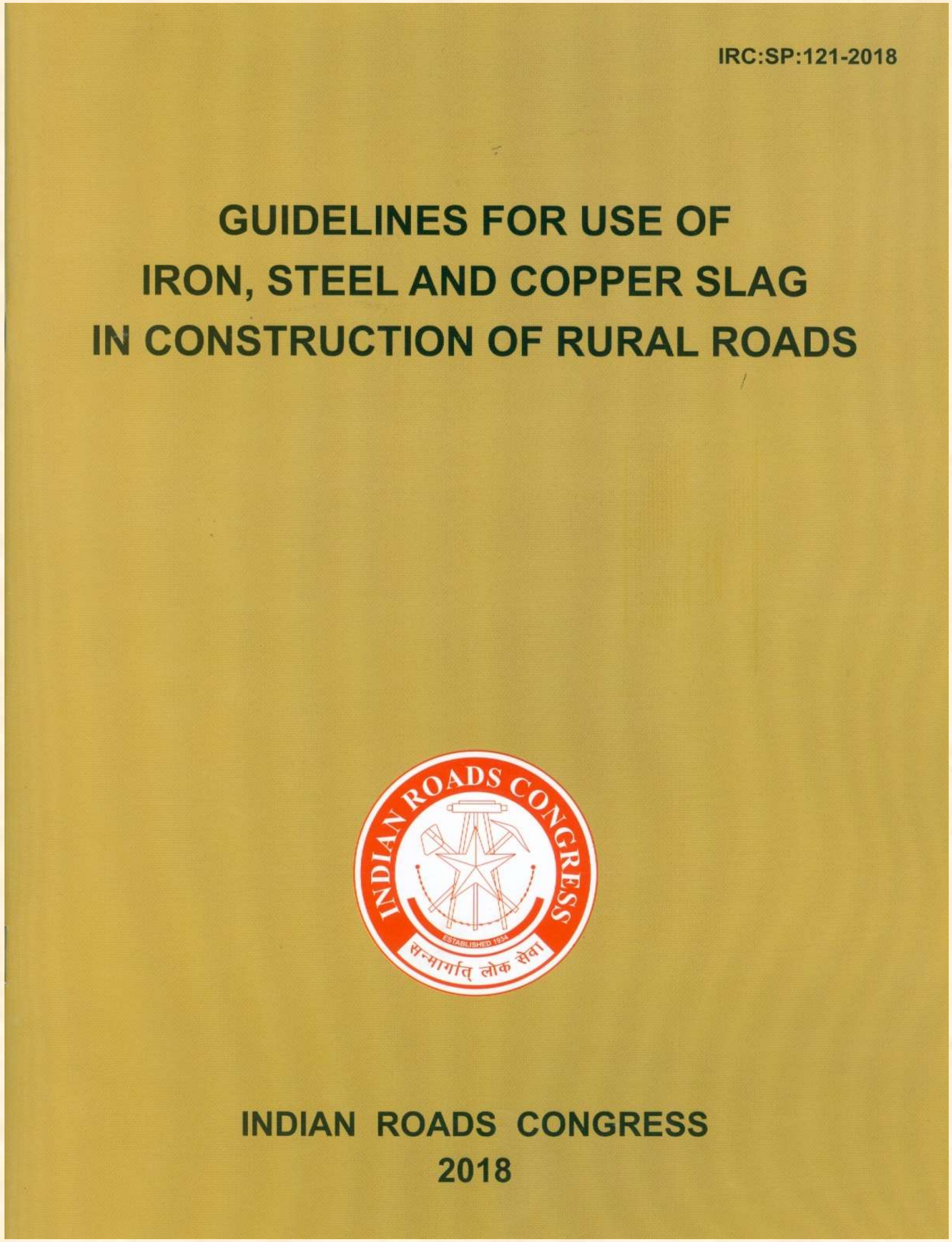
- **Mixing shredded waste plastic, aggregates, bitumen in HMP**

Waste plastic to be injected using pipe under compressed air in a drum mix plant or through an opening over pug mill in batch mix plant, waste plastic should coat over hot aggregates first, bitumen is then added to aggregates, mixed for 15 seconds, loading in trucks

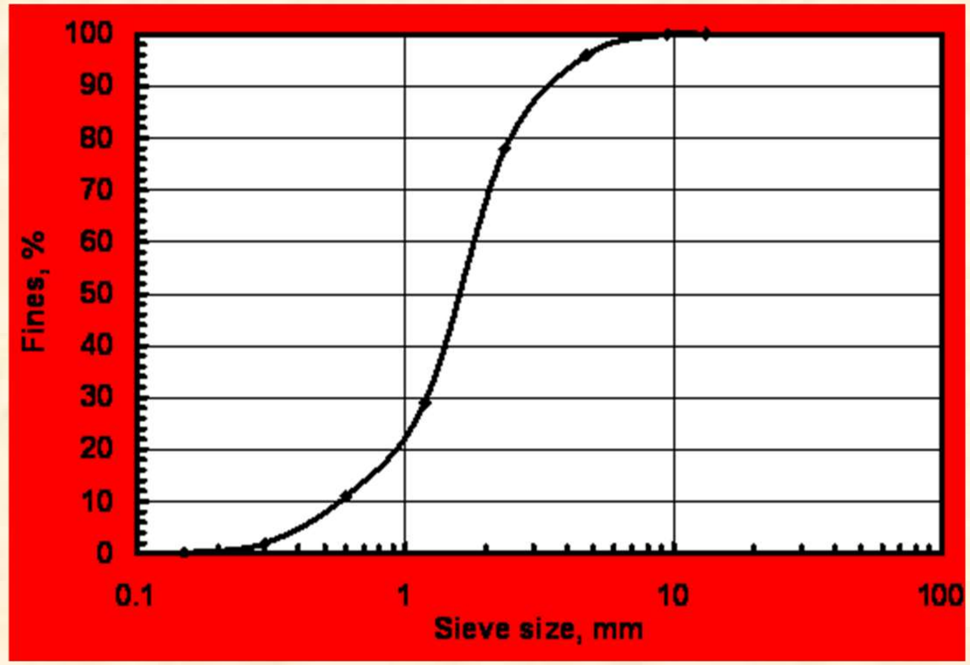


Slag Usage in Road Construction

MORTH Specifications – Crushed slag can be used in GSB, Cement Stabilised layer, WBM, Shoulders



Copper Slag



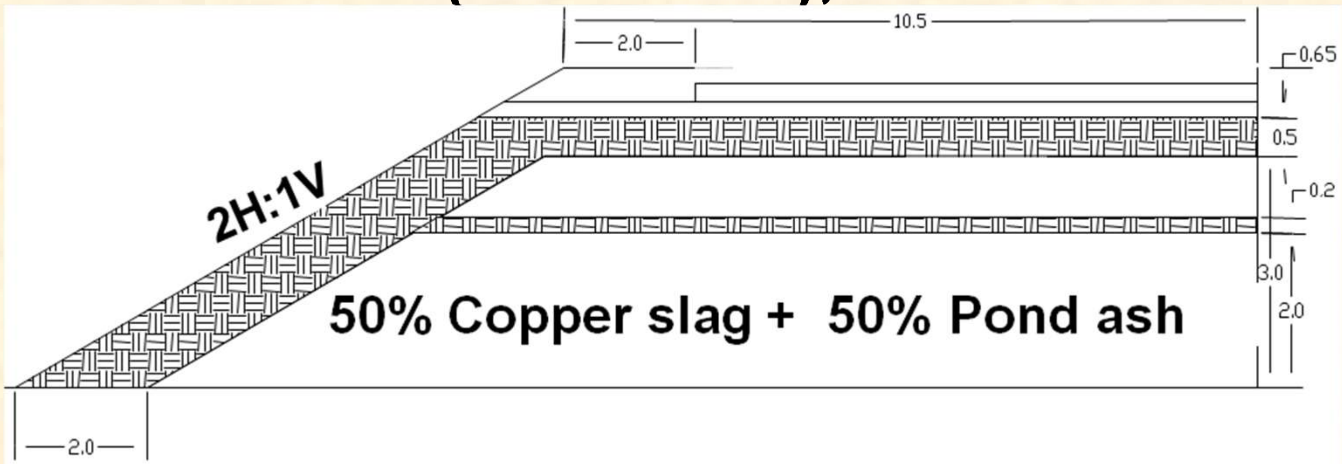
- **Waste from copper smelting – Produced at Dahej (Gujarat) and Tuticorin (Tamilnadu)**
- **Similar to coarse sand in texture**

Water Absorption (%)	Compaction Characteristics		Shear Strength Characteristics		CBR (%)
	MDD (KN/m^3)	OMC (%)	c (kN/m^2)	ϕ (degree)	
1.19	23.2	7.0	0	35	35

Road Construction Using Copper Slag

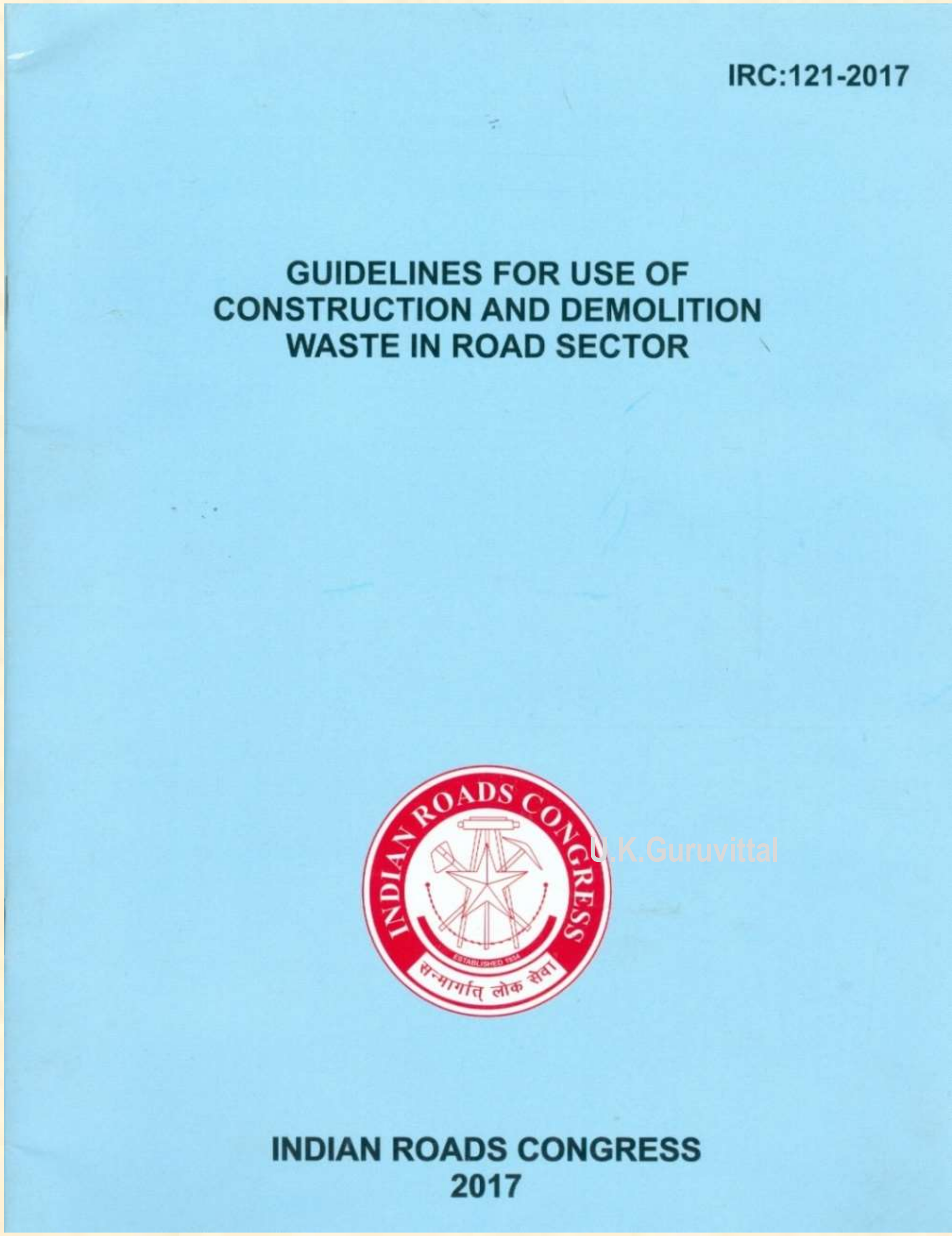
- Copper slag, a granular material poses problems like uneven compaction, shearing of compacted layer by trucks, etc

- Copper slag+pond ash mix found to be workable, used in NH–45 B (Tamilnadu), Performance has been good



Property	Pond ash	Copper slag + Pond Ash (50:50)
MDD (kN/m^3)	12.4	18.8
OMC (%)	21	9
c (kN/m^2)	11.5	0
ϕ (degree)	32	31

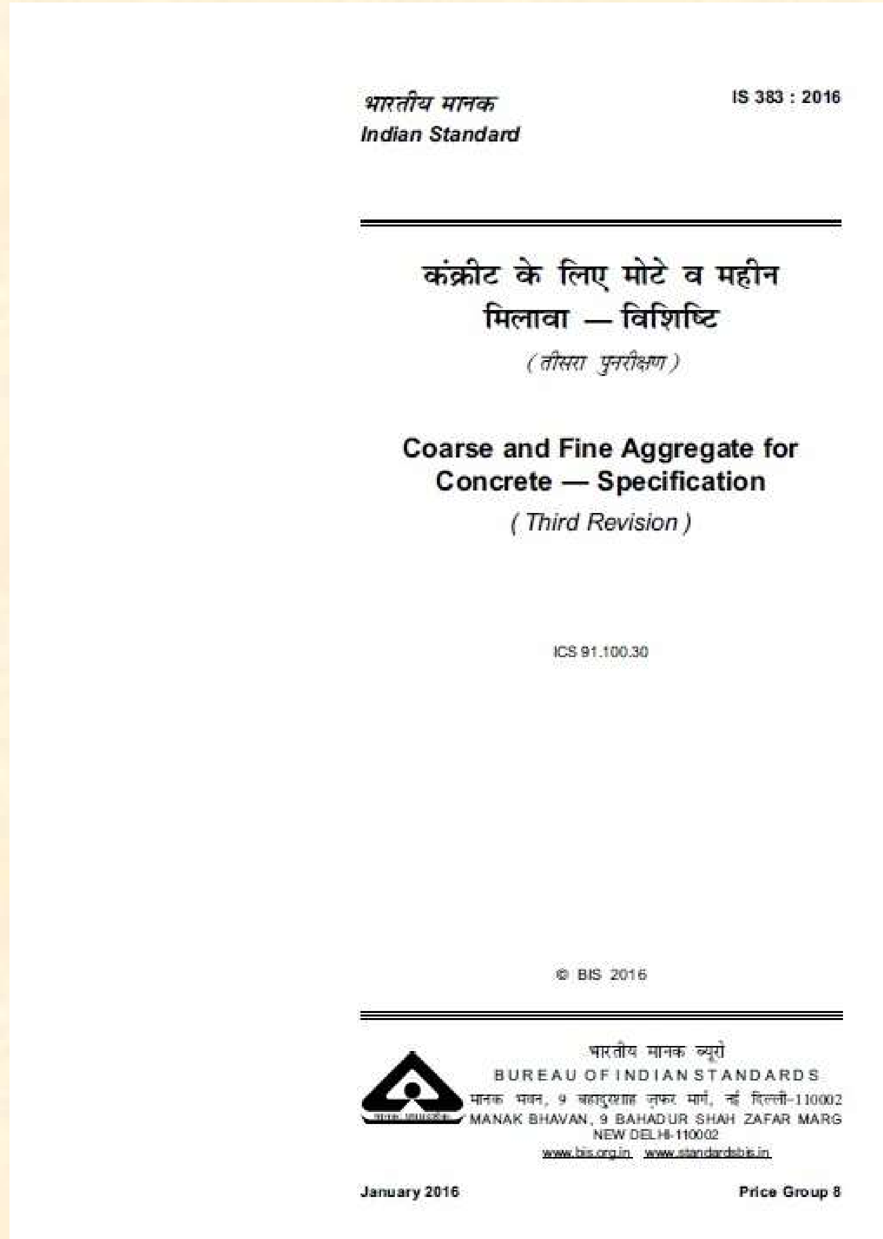
C&D Waste Guidelines – Specifications



IRC:121-2017

GUIDELINES FOR USE OF CONSTRUCTION AND DEMOLITION WASTE IN ROAD SECTOR

INDIAN ROADS CONGRESS
2017



भारतीय मानक
Indian Standard

IS 383 : 2016

कंक्रीट के लिए मोटे व महीन मिलावा — विशिष्टि
(तीसरा पुनरीक्षण)

Coarse and Fine Aggregate for Concrete — Specification
(Third Revision)

ICS 91.100.30

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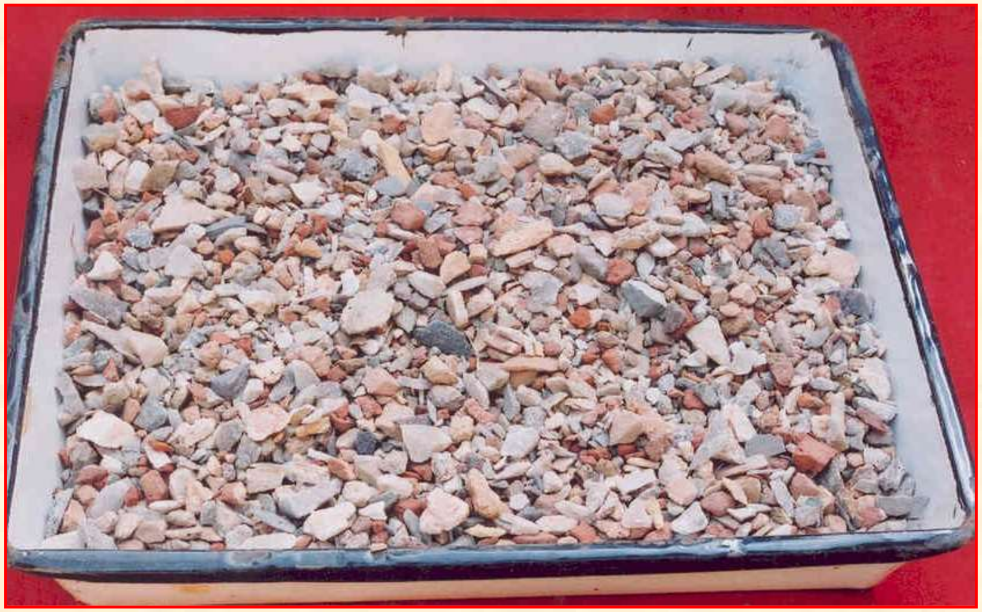
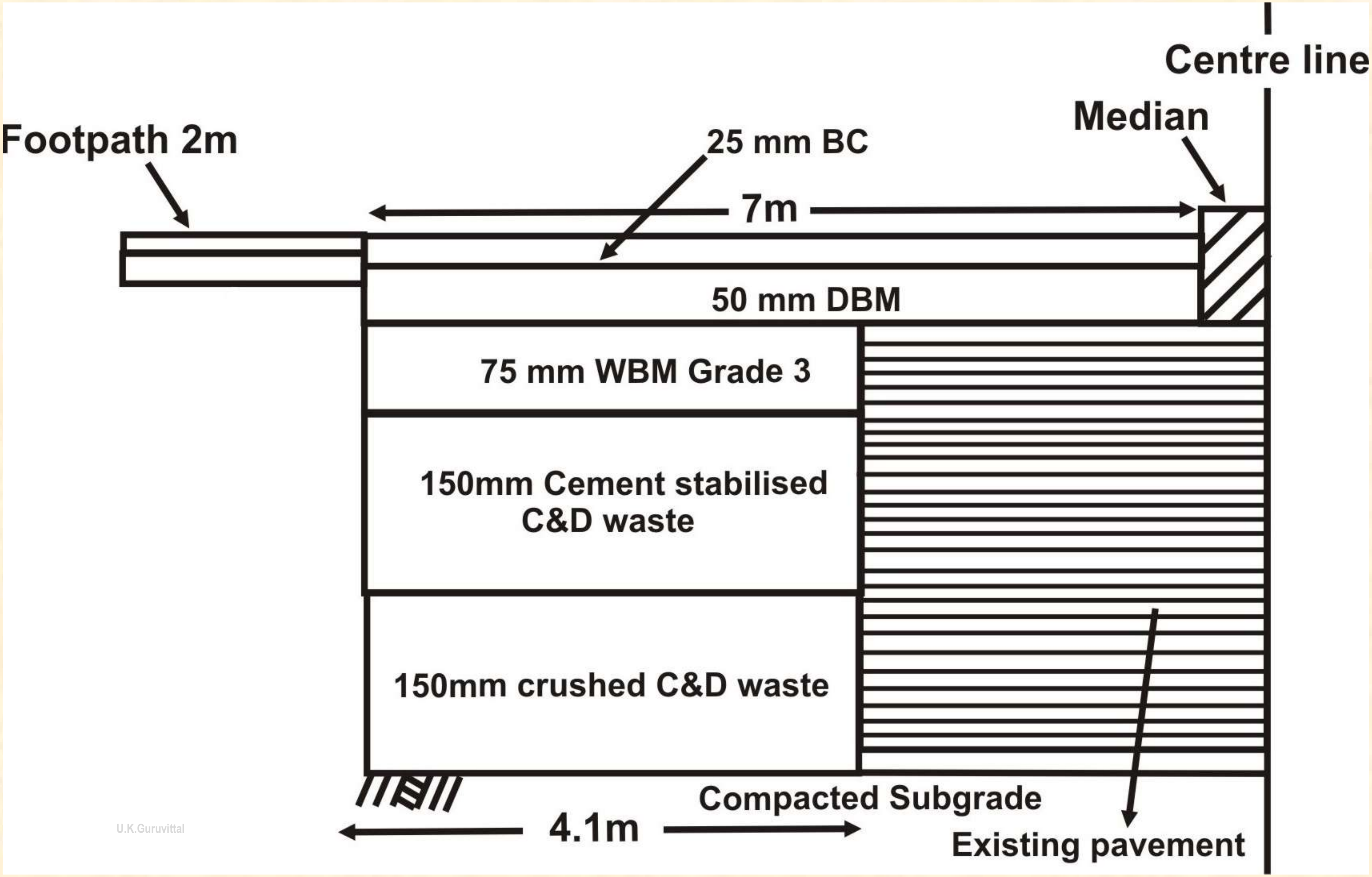
Processed C&D Waste



Test Road Using C&D Waste in Delhi



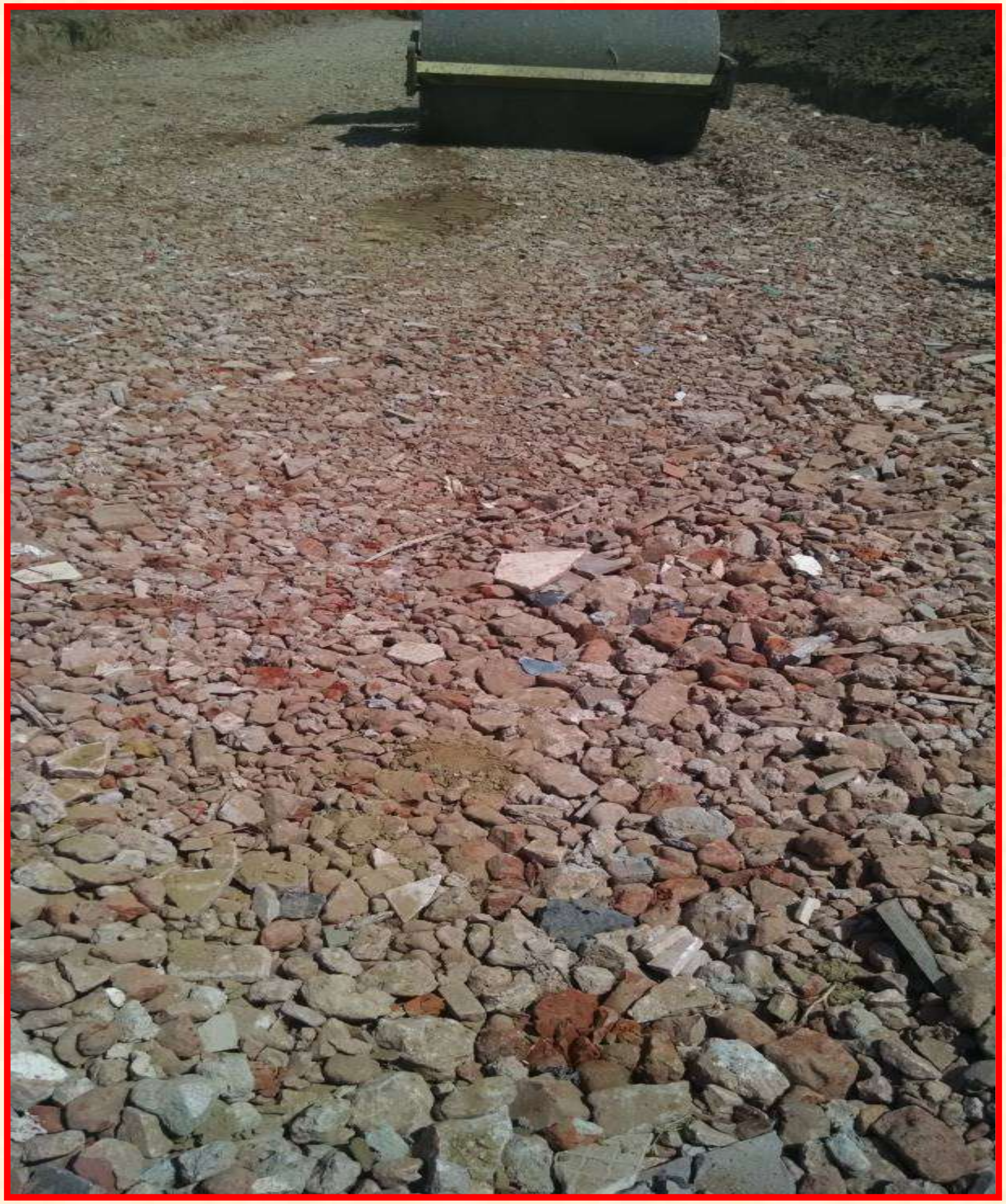
Test Road Using C&D Waste

C&D Waste Use in DDA Road

- **Location** – West Delhi, 100m ROW 4-lane road, 3 km length problematic stretch (NH 10 to Bakkarwala)
- Shallow water table (0.5 to 1 m depth below GL), water logging during rainy season
- SPT & DCP tests showed sub-soil to be weak and in loose condition up to 1.2 m depth, NMC nearing LL
- Replacement of loose sub-soil by compacting crushed C&D waste up to a depth 1.2 to 1.5 m

- Size of crushed RA used ranging from 150 mm to 4.75 mm/ 150 microns, about 2.6 lakh tonnes used
- Successful completion and good performance

C&D Waste Use in DDA Road



C&D Waste Use in DDA Road

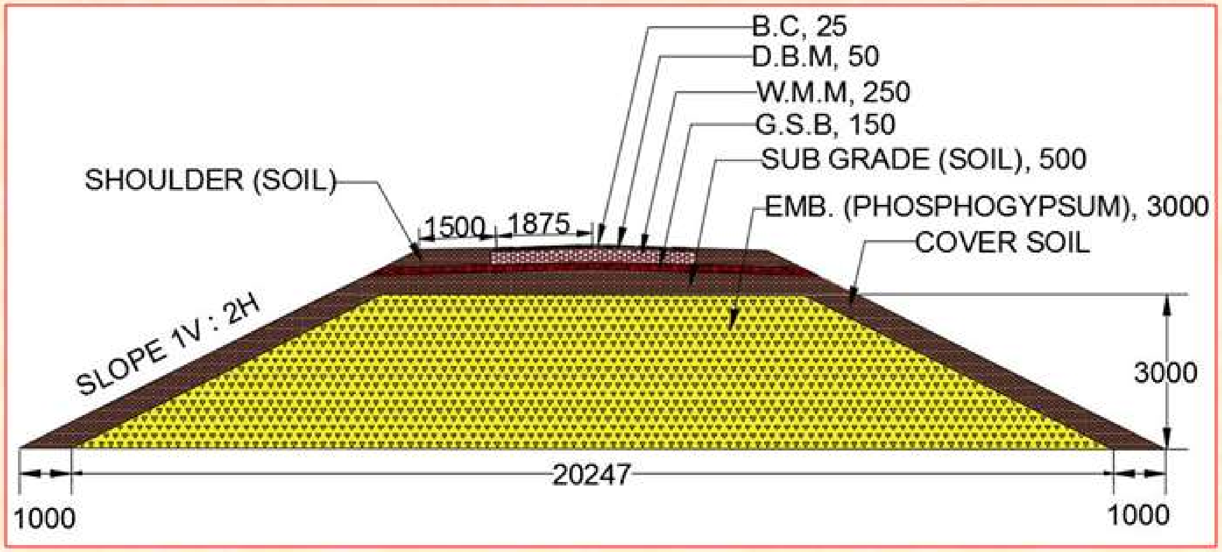
Phosphogypsum

- Waste byproduct from Phosphoric acid industry – Major constituents CaO, SO_3, P_2O_5
- When compacted, it hardens and attains very good strength
- After soaking also, compacted Phosphogypsum retains much of its strength
- Feasibility studies indicated its usefulness for road works

Properties	Phosphogypsum
Maximum Dry Density (MDD) kN/m^3	12.9
Optimum Moisture Content (OMC)%	37
Liquid Limit (%)	42.3
Plasticity Index	Non Plastic
Particle size distribution % of Sand % of Silt	 49 51
Unconfined Compressive Strength (MPa)	5.3
California Bearing Ratio (CBR) %	26

Phosphogypsum Test Road

Guru Vittal



Redmud (Bauxite Tailings)

- Waste from Alumina production – Major constituents Fe_2O_3, Al_2O_3, SiO_2, Na_2O, CaO
- Very high specific gravity, Alkaline in nature, low plasticity and low shrinkage
- Can be mixed with fly ash, lime or cement and used in road works
- Literature reports Redmud usage in road works to be environmentally safe, due to its low permeability, however further tests are needed

Ref: Dr. B Hanumantha Rao, IITBbsr, Dr. S.K.Das, NIT Rourkela, Ms.Parvathi G S, CRRI

Properties	Damanjodi	Muri
Specific Gravity	3.3	2.87
Maximum Dry Density (MDD) kN/m^3	19.8	15.2
Optimum Moisture Content (OMC)%	18	32
Liquid Limit (%)	25	40
Plasticity Index	7	22

Marble Slurry Dust

- About 4000 marble mines and 1100 marble processing units in Rajasthan produce 6 to 7 million tonnes/ annum
- MSD – Causing environmental and disposal problems
- Test track of 750 m length constructed in Nathdwara, District Rajsamand, Rajasthan has shown good performance

Jarofix in Road Works

- Jarosite – Tailing produced during zinc mining, Jarofix – Inert waste produced after stabilising Jarosite
- Feasibility studies on Jarosite / Jarofix indicated their suitability in road works
- However only Jarofix found suitable after leachate study
- Field test track embankment constructed using Jarofix shown good performance




Embankment Construction Using Jarofix

Kimberlite Tailings

- Kimberlite tailings – Waste from diamond mining in M.P
- AIV – About 31%, Can be used in base or sub-base course by adopting mechanical or cement stabilisation
- High value of water absorption (about 6%) makes them unsuitable for use in bituminous pavement

Processed Municipal Waste

- **Processed municipal wastes** used for construction of test track in a village road near Delhi
- **Sub-base** constructed using **cement stabilised** municipal waste
- **Performance** of stretch was **good**

Step Wise Procedure for Using Local Materials

- Identifying the local material to be used in road works – Quarry or mining waste, Fly ash, Slag, C&D Waste, etc
  - From local enquiry / Industries Department
- Whether it is in the form of Coarse aggregates or Sand or a Combination of the two ? Refer to MORTH/ MORD Specifications
  - Aggregates can be used in WMM / GSB / WBM depending upon AIV
  - Sand type material can be used in Sub-base
- Characterise the material – Subject it to Engineering Tests
  - Depending upon mode of usage (Aggregate or Sand or Soil + Aggregate Mix) relevant tests to be conducted
  - Aggregate type – Gradation, AIV, Water absorption, Flakiness index
  - Sand type or Soil + Aggregate Mix – Gradation, Plasticity, Proctor test, CBR
- If the material is a waste from an Industry – Environmental Acceptability Tests

Step Wise Procedure....Contd

- Based on the results of engineering test results, decision to be made to use it as such or to use it after improvement
  - In case local material properties meet specification requirements for use as such, it can be directly used in road construction
  - If local material properties do not meet specification requirements, Additional tests for using it after improvement are required
- Improvement can be mechanical stabilisation or additive stabilisation
  - Compacting to Modified Proctor Density can impart higher CBR
  - Mixing conventional aggregates or intermixing two or more local materials can improve gradation, there by enhancing strength or decreasing plasticity
  - If both above options, are not giving desired results, cement or lime stabilisation may yield compressive strength to meet Specifications

- Using in Wearing Course – Laboratory tests
- Entering into an agreement with waste generator for supply of the material

Step Wise Procedure.....Contd

- **Mix design** to be adopted for pavement layer
  - Optimum mix for cement concrete or mechanical stabilisation or quantity of cement / lime to be determined after laboratory trials
- Pavement design as per **IRC Guidelines** after finalising the mix design for stabilisation
- **Rate analysis** for the local material to be used and approval
- Preparing the **DPR incorporating the local material** and also ensuring conventional road section to monitor performance
- **Construction** of the road
- **Performance monitoring** for Two years (Completion of two rainy seasons)
- Publishing the results and **planning wide scale usage** of local material if trials are successful


Thank you
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