Title - Bulk Recycling of Jarofix Waste Material for Road Construction

Project Leader - Dr. A K Sinha, Head and Senior Principal Scientist

Uniqueness – First time carried out Globally, New Concept and new Application

Date of commencement – First Tour was made in 2006.

Laboratory Study (Phase-I) – Started in 2009 and completed in 2010.

Pilot Study (Phase – II) – Started in 2010 and completed in 2015.

Bulk Utilization (Phase-III) – Started in 2019 and Till continuing.

Major Milestone – 5 lacs ton Jarofix has been used in Road.

Jarofix Production – 3 lacs Ton/year, deposited – 100 lacs ton at HZL, Chittorgarh

List of Tangible and Intangible Benefits

Tangible

- Reduction in carbon footprint in the form of Green house gas emission (CO_2 & CH_4)
- Reduction in the cost of road construction.
- No toxicity leachate concentration of Heavy Metal.

Intangible

- Jarofix is alternative to conventional soil.
- Conservation of fertile soil results in sustainable road.
- The costly dumping area will be free for developmental work.
- Development of guidelines would result in awareness.
- Research papers have been published will help to the society.
- Maintenance cost of Jarofix dumping yard will be stopped.

Replication potential of project within sector

- Research paper publication (Total -13).
- Presenting Research Works - International/National Seminar.
- Publication of IRC guidelines – IRC SP 132 (2022).
- Technical Training to Field Engineers.
- Training program for national/State Governments and Private Engineers at CSIR-CRRI, IAHE Noida, Colleges.
- Teaching B. Tech, M. Tech and Ph. D Students.
- Saving of conventional fertile soil by Jarofix will reduce cost of construction.
- Developed design specifications and methodology will be same for all jarofix.
- The technology developed will be used by other countries.
- Technology leads to large scale field application, this will result in employment.

Challenges/Barriers

Technical

- The main challenge is its engineering properties.
- Uncertainties of its engineering properties.
- Lack of availability of the design codes/standards.
- Not meeting standard specifications (MORTH/MORD/PWD).
- Risk factor about the performance, Durability of material.

Administrative

- Lack of awareness, Lack of skill and construction methodology.
- Getting Site for the construction is big issue.
- Poor adaptation attitude of government policy makers.
- Most of these wastes are not accredited in IRC.
- Search for alternate road materials

Challenges/Barriers(Cont.)

Maintenance

- Industrial waste materials generated in huge quantity.
- These waste are simply dumped as very limited use.
- Creating environmental problem and occupying costly land.
- Limited research has been done on these wastes so far.
- These wastes have potential for utilization in road construction.
- Maintenance of Jarofix dumping Yard

Countering Challenge

- Laboratory Characterisation of Jarofix.
- Comparing with available IRC/MoRTH Guidelines.
- Performance study in the laboratory.
- Comparing the performance with similar materials.
- Technical discussion among stack holders (NHAI, PWD, Agenics, CPCB).
- Conducting Workshop.
- Construction of experimental Jarofix Road – Pilot study.
- Performance monitoring of the Jarofix Road.
- Development of Guidelines.

Scope and Objectives

1. Determination of Properties of Material
2. Design of Embankment/Subgrade/GSB
3. Performance Evaluation in the Laboratory
4. Development of Construction Methodology
5. Performance Evaluation in the Field
6. Environmental Feasibility
7. Economic analysis
8. Development of Guidelines

Sequence of studies

Steps	Objectives
1. Chemical Analysis	Hazardous/Non
2. Engineering Properties	As per standard Procedures
3. Laboratory Model study	Performance study
4. Accreditation of materials	IRC
5. Field construction	Performance study
6. Development of guidelines	IRC/CRRI

Methodology

A. Collection of Jarofix – Hindustan Zinc Limited, Chittorgarh

B. Laboratory Study

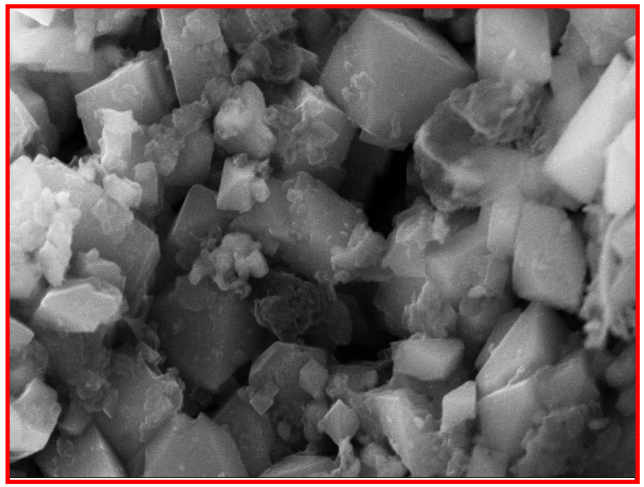
1. Physical, Chemical and Geotechnical Characterization.
2. Mechanical/Chemical Stabilization.
3. Design and Stability Analysis of Embankment.
4. Laboratory Physical Model Study.

C. Field Study

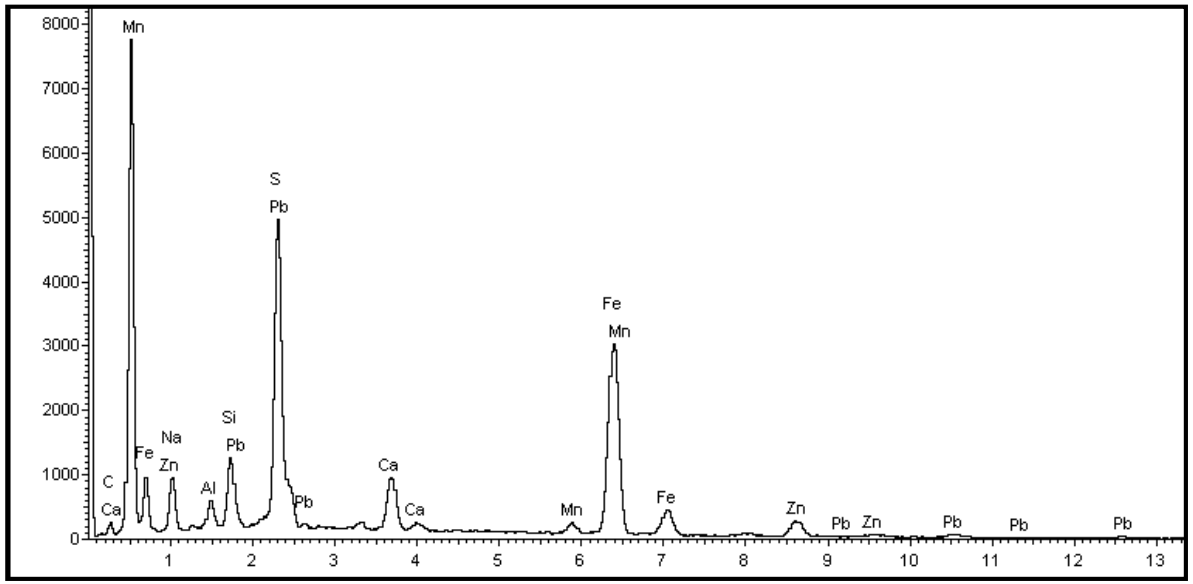
1. Construction and Compaction of different Layers.
2. Economic Analysis.
3. Environmental Feasibility.
4. Performance Monitoring.

D. Bulk recycle of Jarofix

Physical and Chemical Characterization



SEM of jarofix

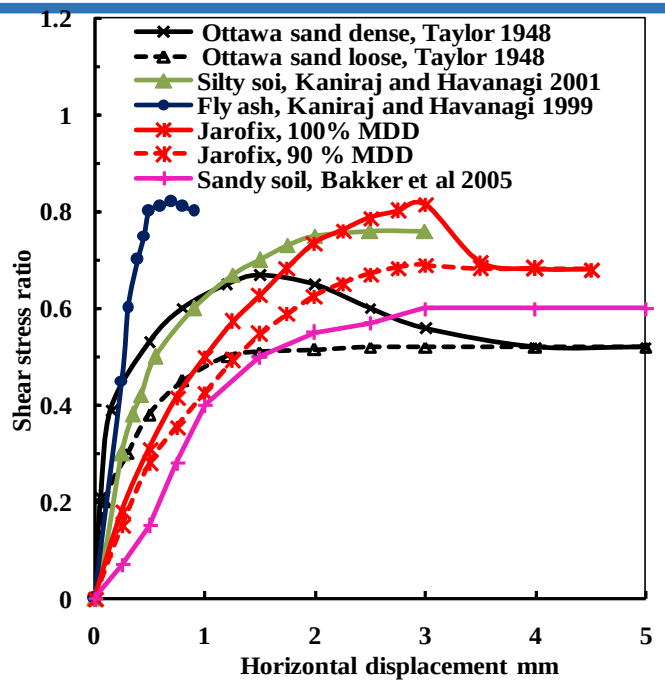


EDS Spectrum of jarofix

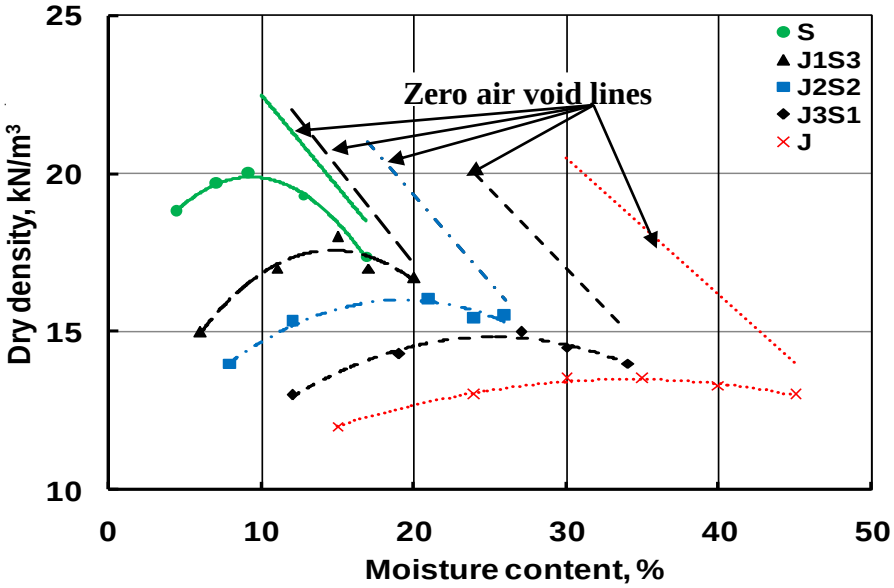
Concentration of heavy metals, mg/kg

Sample	Zn	Pb	Cd	Ni	Co	Mn	Fe	Cr	Cu
Jarofix	2614	247	38.14	1.9	0.03	417	3.4	Nil	50
MEFCC, 2016 Regulatory Limit	20000	5000	50	5000	5000	N.S.	N.S.	5000	5000

Geotechnical Characterisation



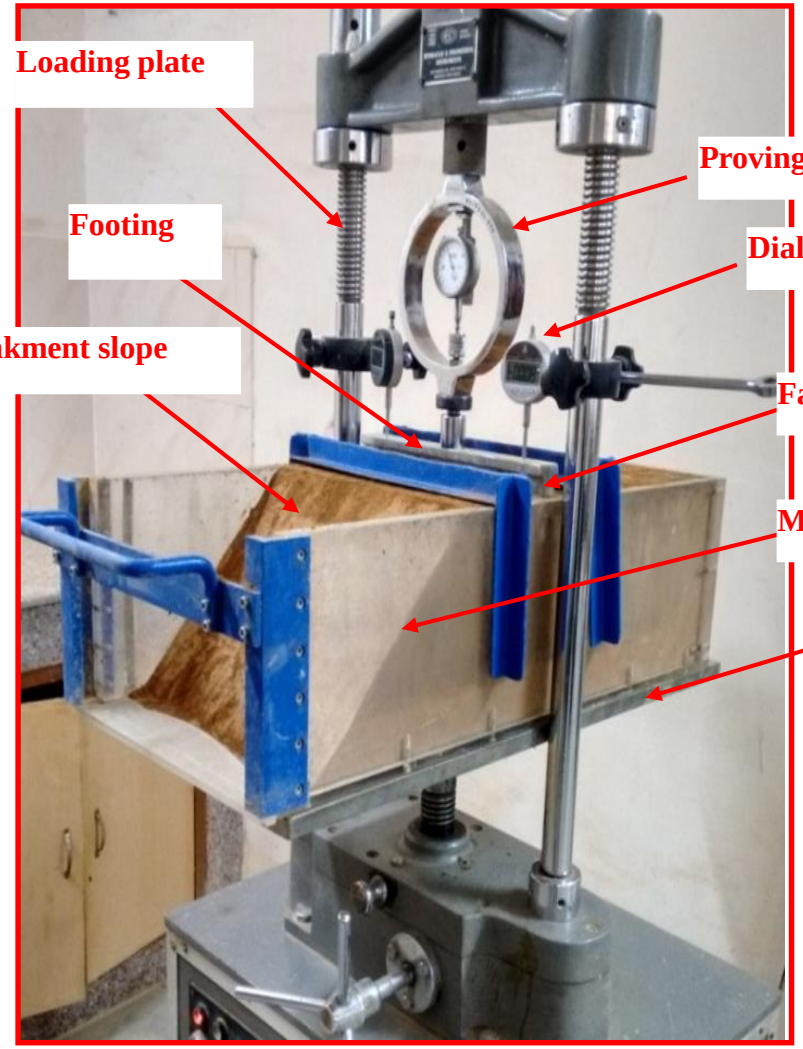
Stress ratio ~ Displacement of jarofix



Results of durability test of cement stabilized jarofix

Type of material	Classification as per AASHTO	Jarofix stabilized with cement loss (%)			Permissible soil cement loss (%) ASTM D559 and IRC 37
		Jarofix + 3 % C	Jarofix + 6 % C	Jarofix + 9 % C	
Jarofix	A4	Failed	6	5	2 - 11 (3 – 5 %)

Performance study by Laboratory physical model test



Parameters Studied

1. No. of reinforcement layers
2. Slope of embankment,
3. Vertical spacing of reinforcement
4. Width of footing
5. Edge distance from the slope

Geotechnical Properties

Property	Jarofix	MoRTH/IRC specifications
Maximum particle size, mm	< 10	75, 50
Liquid Limit,%	59	< 70
Plasticity Index, %	43	< 45
Density, g/cc	1.4	1.5, 1.6, 1.75
OMC, %	22	--
FSI, %	10	50
ϕ, degree	22	-
c, kN/m^2	14	-
CBR, %	6	-
UCS kN/m^2 (6 % / 9% cement), 7 days	2.2 MPa 4.8 MPa	1.5- 3 MPa/ 4.5 MPa
Durability	Pass	Wetting & drying/Residual

Embankment Construction using Jarofix

Site – SH 9 Udaipur –Chittorgarh

Total length of road – 300 m

Used in one lane widening portion

Section I – Jarofix Section II – Jarofix:soil (50:50) Section III – Soil

Construction of Embankment

Existing road

Compacted virgin widened lane

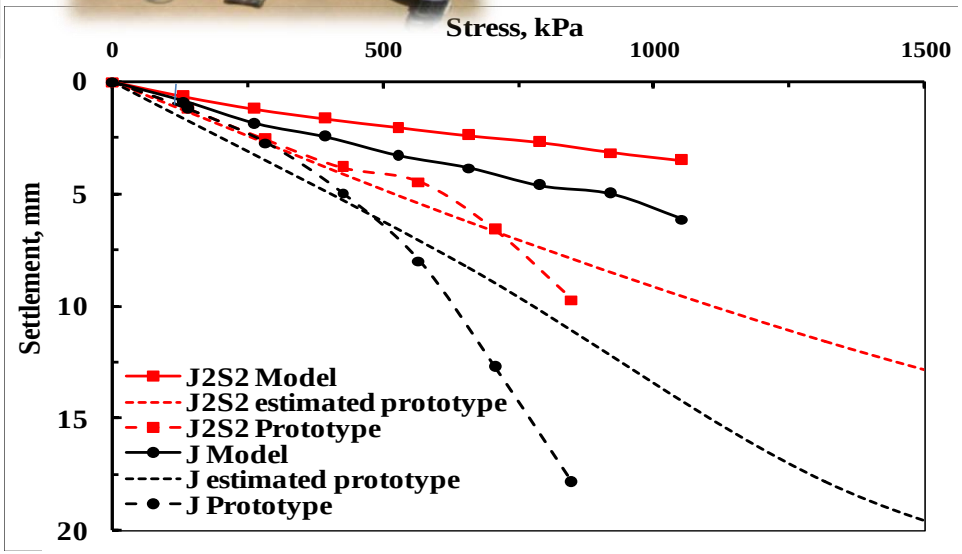
Mixing of soil and jarofix

Evaluation During Construction

- Density
- Modulus
- CBR
- Gradation
- Moisture
- Thickness

Modulus of Elasticity, MPa

Material	Lab. study	Field study	
	Model test	Prototype test	Estimated prototype
Jarofix	5.11	12.8	14.2
Jarofix-soil	8.18	22.5	21.5



Settlement ~ Failure stress (field & lab. tests)

Performance Monitoring

1. Visual Condition Survey

   (cracks, rutting, potholes, raveling, distress)

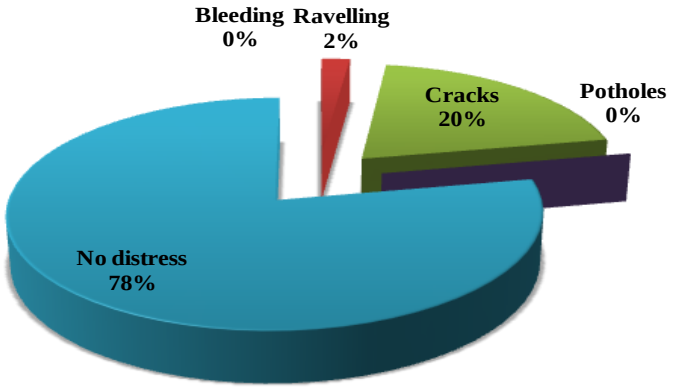
2. Deflection and Roughness Measurement

3. Settlement Measurement

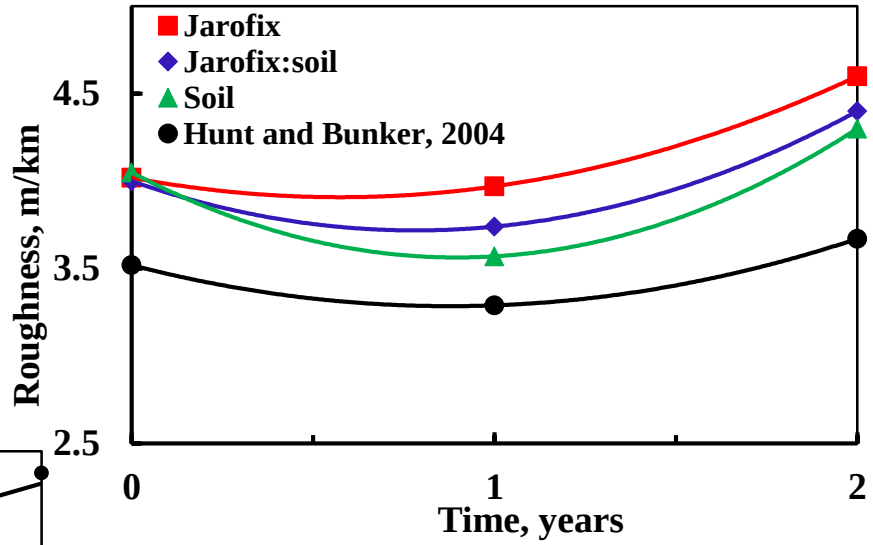
4. Environmental Assessment

Visual Condition Survey & Performance

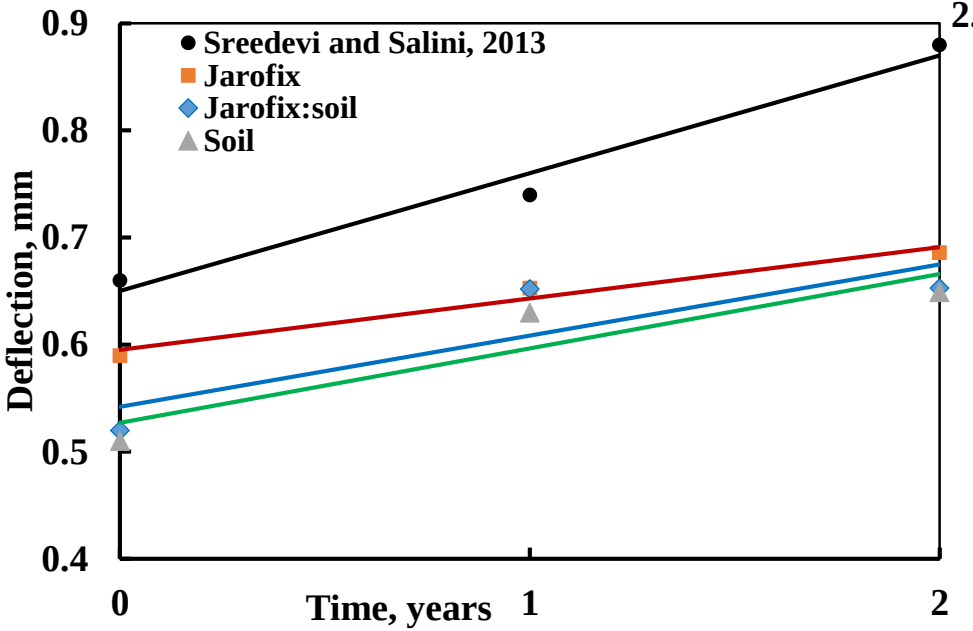
Performance cont.



Condition survey of pavement



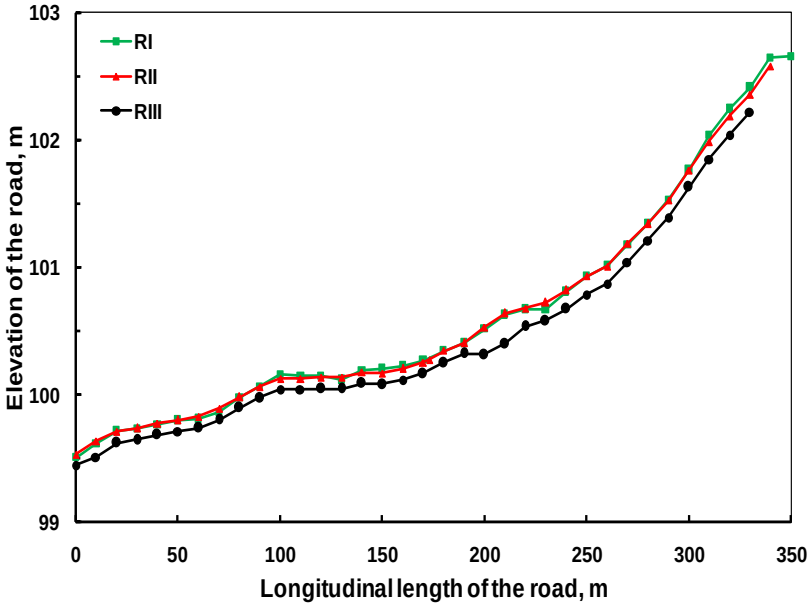
Variation of roughness ~ time

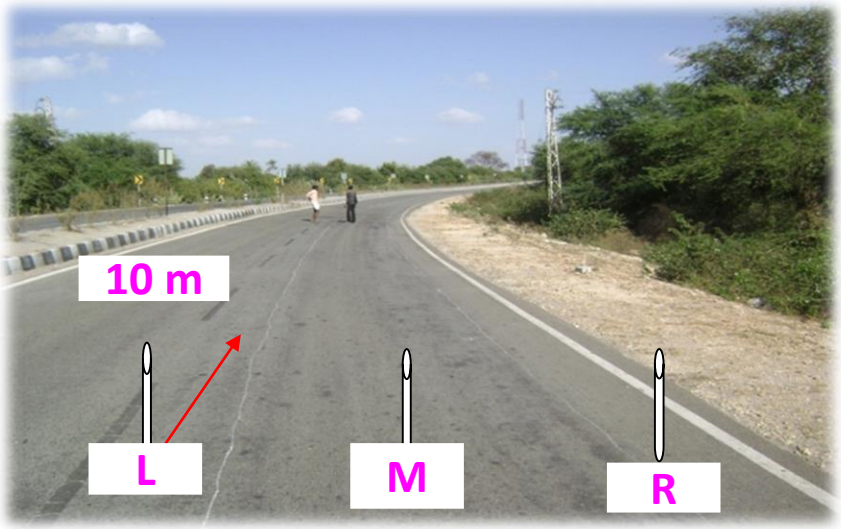


Variation of deflection ~ time

Settlement Analysis

Performance cont.



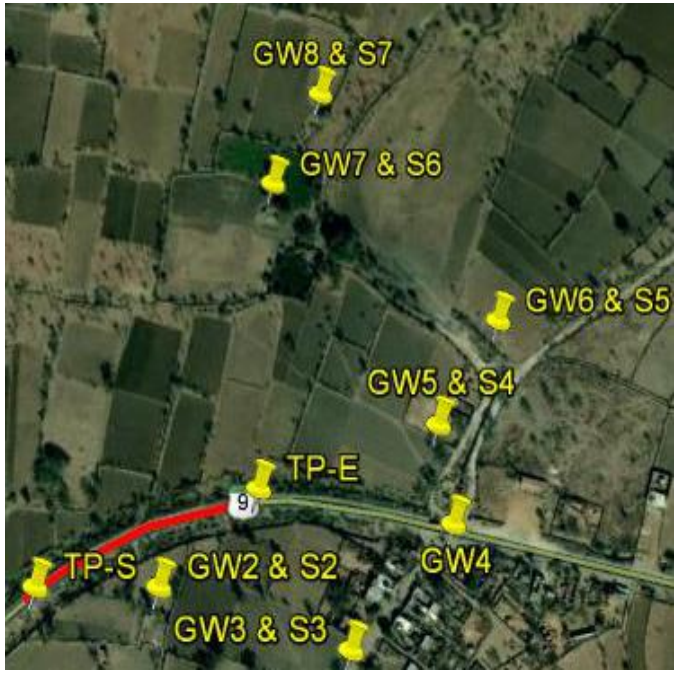


Settlement

1. Consolidation test
2. Laboratory physical model test
3. Actual measurement in the field

Environmental Assessment

Performance cont.



Pre–Post Construction Monitoring of Groundwater and Soil

- **Ground water monitoring: 8 wells**
- **Soil chemical analysis: 8 locations**
- **Leachate collection and analysis at actual site**

Heavy metal concentration (TCLP)

Performance cont.

Sample ID	Zn (mg/l)	Pb (mg/l)	Cd (mg/l)	Ni (mg/l)	Co (mg/l)	Mn (mg/l)	Fe (mg/l)	Cr (mg/l)	Cu (mg/l)
Tank 1	0.454	0.176	Nil	Nil	Nil	0.85	1.08	0.007	0.015
Tank 2	0.031	0.004	Nil	Nil	Nil	Nil	0.047	0.001	0.01
MEFCC 2016 Regulatory Limit	20000	5000	50	5000	5000	N.S.	N.S.	5000	5000

Economic Analysis

Sl. No.	Activity and rate	Jarofix	Soil
1	Royalty given to the farmer for material (soil considered as minor mineral) @ Rs. 25 per cubic meter	Nil	37500
2	Sprinkling of water at the borrow area before excavation @ Rs. 1 per cubic meter	Nil	1500
3	Excavation, pulverization of lump, picking of roots, stems, plastic etc. at borrow area @ Rs. 1 per cubic meter	Nil	1500
4	Transportation cost (bringing the material at the site) @ Rs. 2 per cubic meter	Nil	3000
5	Mixing of water to obtain OMC, compaction and rolling @ Rs. 1 per cubic meter	Nil	1500

Cost saving of Rs. 4.5 lacs/ km in comparison to soil.

Workshop and Technical Discussion

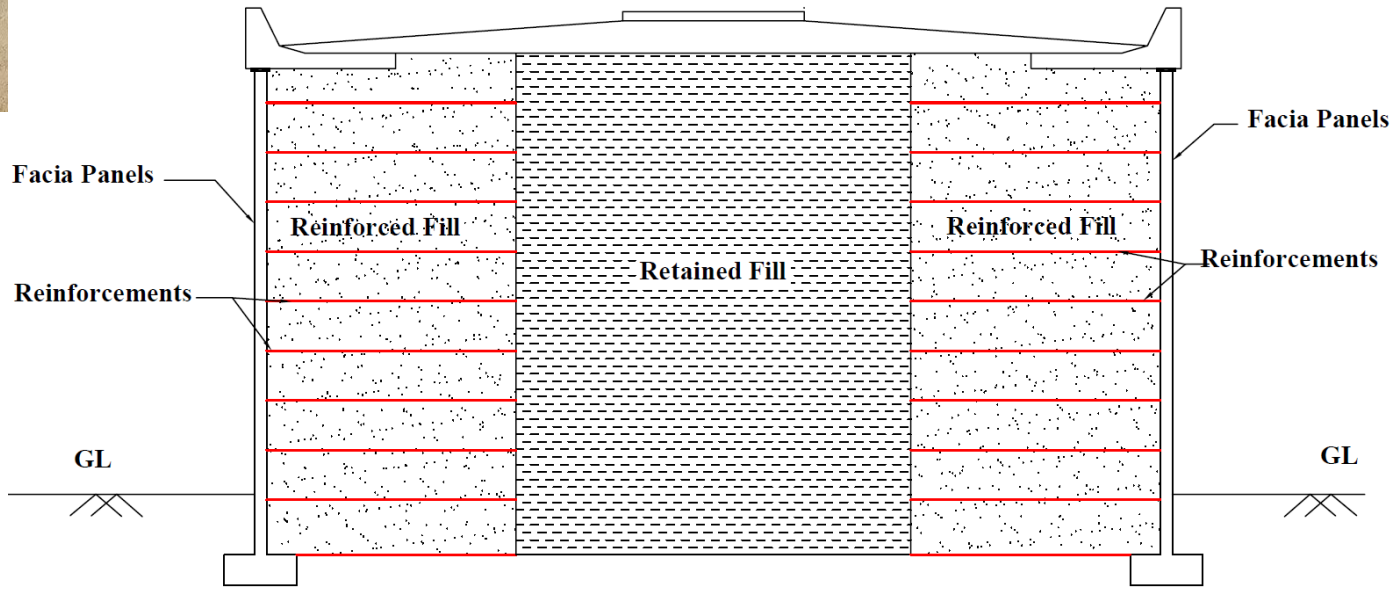
Workshop on jarofix and slag at Chittorgarh

Technical discussion among different officials

(CSIR-CRRI, HZL, HGIEL)

Bulk Recycle of Jarofix as Retained Fill of R E wall Road Construction

NH-76
Udaipur to Bhilwara
(Rajasthan)



MIXING OF JAROFIX AND SLAG

Stacking of jarofix and slag layer by layer

Stacked partially mixed jarofix-slag at the site

Construction and Performance study

Top layer of the jarofix-slag retained fill

Finished Road and performance study is in progress

Bulk Recycle of Jarofix as Retained Fill of R E wall Road Construction

NH-80

Kota (Rajasthan)

Under Construction

Achieving national benchmarks/Standards

At present there is no any competitor in the country as well as globally.

Top best practices and Priority Plan in +1 To + 2 years

- Recycle of Jarofix in embankment Road Construction.
- Recycle of Jarofix in Subgrade Road Construction.
- Recycle of Jarofix as a retained fill of approaches of flyovers.
- Recycle of Jarofix in stabilized granular sub base layer Road Construction.

Skoch Award 2017

Order of Merit Award

Title- Jarofix solid waste material from zinc industry for road construction

CIDC Vishawakarma Award 2018

Achievement award for the best project

Title of Project- Jarofix Waste Material for Road Construction from Zinc Industry.

Conclusions (Major Learnings)

- **Properties of Jarofix are suitable for embankment and subgrade construction.**
- **Construction methodology developed by using conventional equipment.**
- **Jarofix waste is suitable alternative material of soil.**
- **Recycle of theses wastes will protect the environment and society.**
- **Economizes the construction cost.**
- **Performance is as good as soil.**
- **5 lacs ton has been used in road construction.**
- **IRC SP 132 (2022) Guidelines on Use of Industrial Wastes for Road Embankment and Subgrade Construction.**

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