Revolutionizing Road Infra with Modern Equipment, Technologies, Sustainable Materials and Policy Guidelines

February 29th - March 1st, 2024, Manekshaw Centre, New Delhi

Presentation on

STEEL SLAG ROAD: A SUSTAINABLE UTILIZATION OF PROCESSED STEEL SLAG AGGREGATES IN ROAD CONTRUCTION

WASTE TO WEALTH
Swachh Bharat Unnat Bharat

Satish Pandey
Principal Scientist & Associate Professor
CSIR-CRRI, NEW-DELHI

International Road Federation
India Chapter
INDIA CHAPTER

www.indiairf.com | india@irf.org.in

Overview of Steel Slag in INDIA

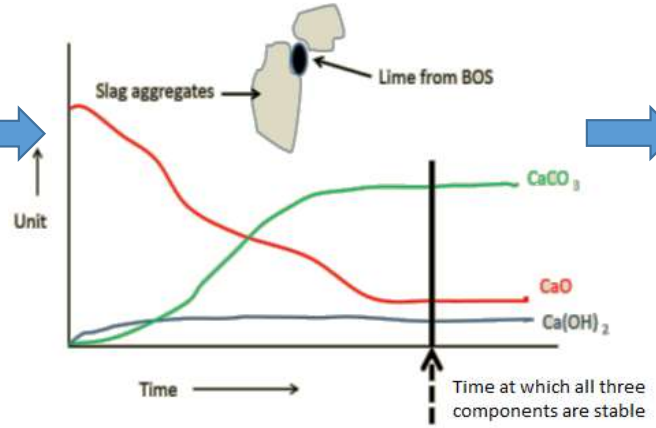
- Around 19.5 million tonnes of, steel slag is generated every year in India from various integrated steel plants
- National steel policy 2017 envisages the crude steel production in the country will be nearly 300 million tonnes by 2030-31
- Accordingly, the steel slag production is also likely to increase to 60 Million tonnes by 2030-31
- Disposal of steel slag is a major concern for steel industries as it is considered as a waste material and largely disposed of as a land fill or piled up inside the steel plants
- Conversion of RAW steel slag as Processed Steel Slag Aggregates exhibits great potential as a substitute of natural aggregate for Steel Slag Road Construction
- Massive National Highway Development program posed a unsustainable demand of of natural aggregate for road construction, which is presently around 1.1 billion tonnes per annum
- This demand is slated to increase by 2.2 billion tons by 2025. Potential utilization of processed steel slag aggregate as substitute of natural aggregates can meet out this demand partially

Major Challenges with Steel Slag: Volumetric Instability

Free Lime Pocket in Slag

$CaO + H_2O$ (approx 15 to 19 % expansion) produces $Ca(OH)_2$

$Ca(OH)_2 + CO_2$ (air) (approximately 12 to 15 % expansion) produces $CaCO_3$



High volume expansion potential in the presence of moisture

Major Challenges : Vesicular Structure and Tufa Formation

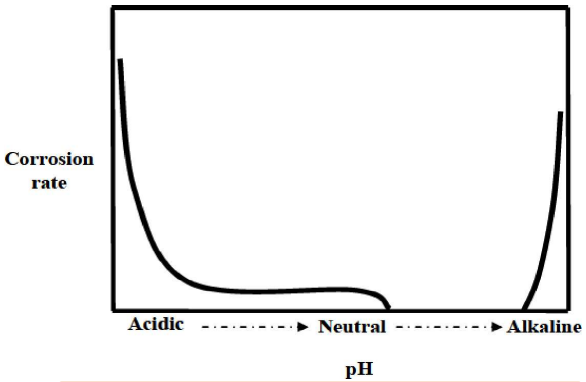
The major Carbonation Reactions :

- □ **(Ca,Mg)SiO3 +CO2 →(Ca,Mg)CO3 +SiO2**
- □ **Ca(OH) +CO + H O→CaCO + 2HO**
- □ **Mg(OH) +CO + H O→MgCO + 2HO**

(c) Enlarged image of steel slag aggregate displaying the presence of coating of calcite

Major Challenges : Corrosion Potential of Steel Slag

Steel slag exhibit higher corrosivity than natural soils. Especially when steel slag is to be used in unbound applications (embankment, road bases, etc.), the corrosion potential of steel slag should be evaluated carefully



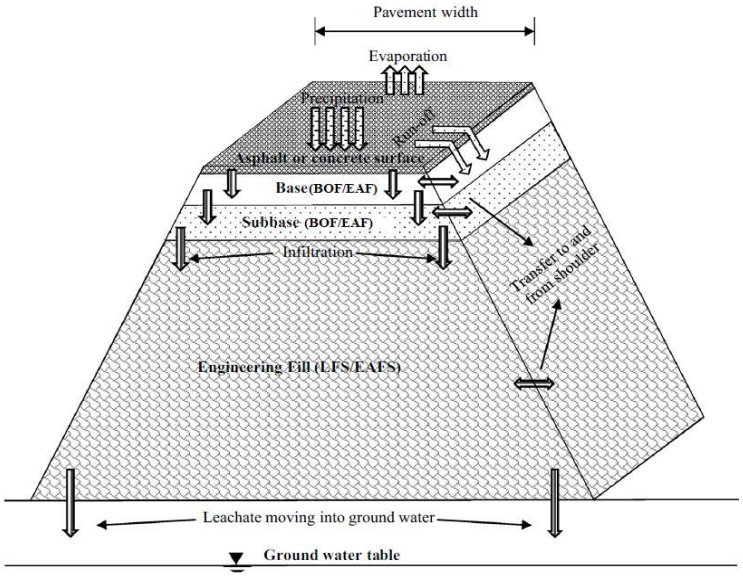
Effect of pH on Corrosion Rate

Corrosion in BOF Slag Aggregate

Corrosion Stains in Concrete

Corrosion susceptibility of Slag Aggregate can be evaluated by determining the Metallic Fe fraction in slag aggregate

Major Challenges : Environmental Concerns



Source of High pH Leachate in Road

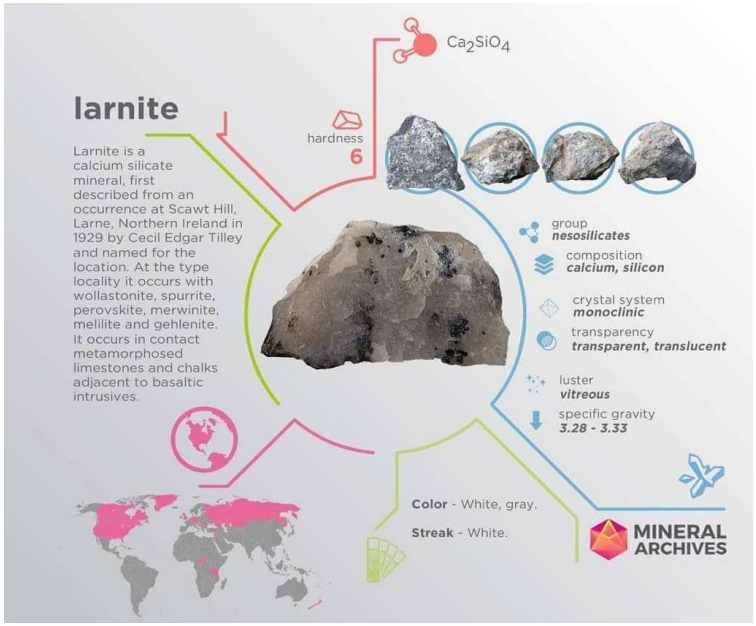
Leachate Contamination in Native Soil and Water Bodies

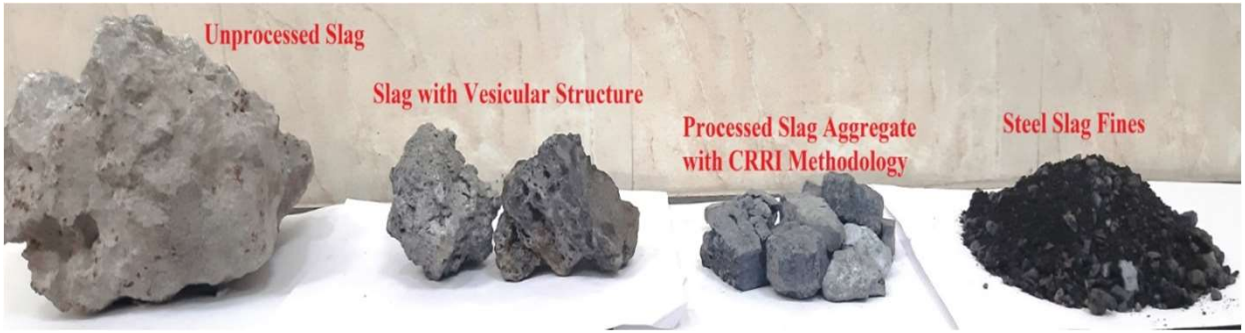
Steel Slag Valorizations as Road Making Aggregates

Typical Mineralogical Phases in Steel Slag

S.No.	Mineral Name	Structural Formula
1	Larnite	β-Ca_2SiO_4
2	Srebrodolskite	$Ca_2Fe_2O_5$
3	Tricalcium silicate	Ca_3SiO_5
4	Spinel (Fe,Mg,Mn,Al)	$Me^{2+}Me^{3+}{}_2O_4$
5	Wustite	FeO
6	Calcite	CaCO3
7	Periclase	MgO

Beneficial Mineralogical Phases can be Maximised in Steel Slag by Controlling the steel slag processing and methodology in liquid state





Steel Slag Processing as Road Making Aggregates

Molten Slag Controlled Air Cooling

Magnetic Separation

Secondary Crushing

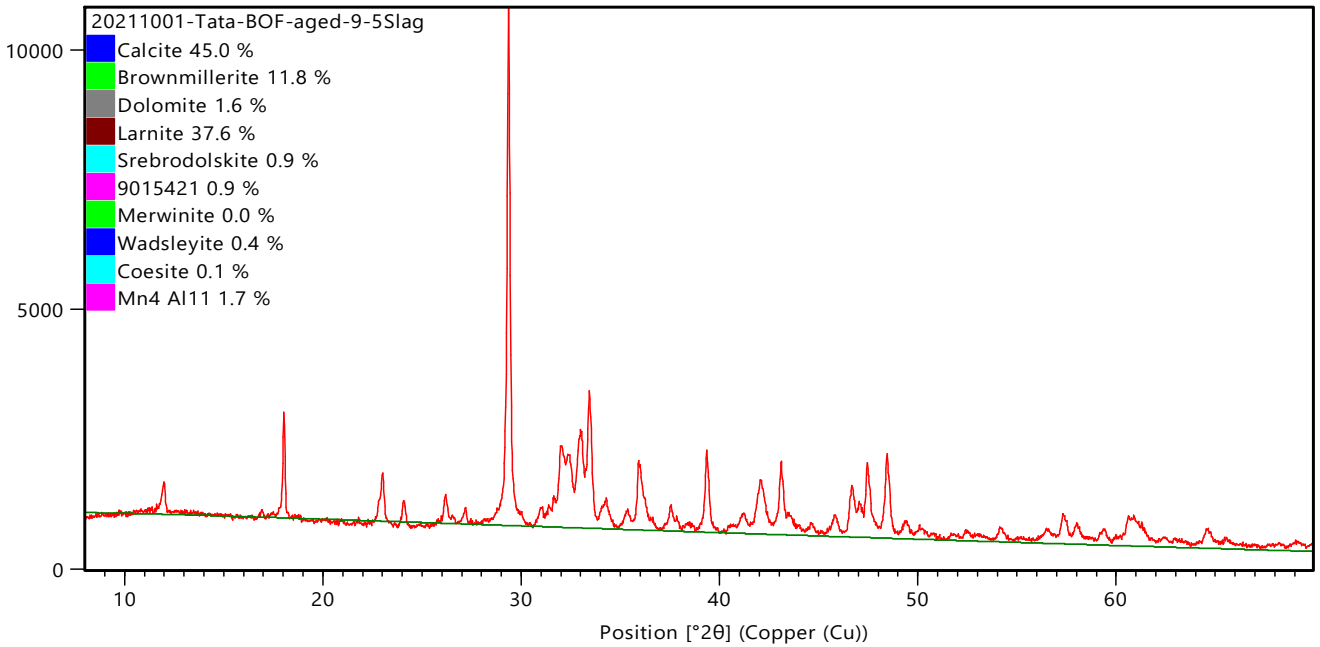
Transportation to the Slag Yard

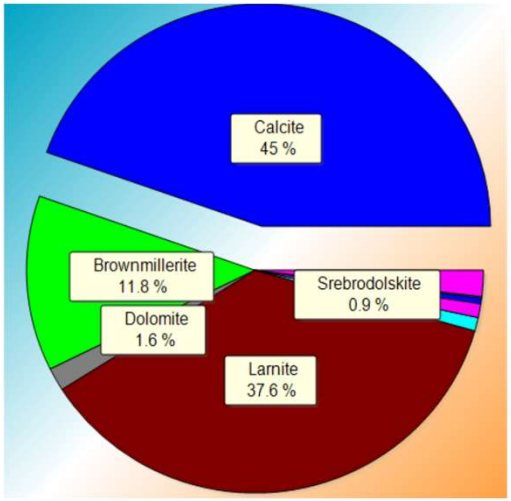
Primary Crushing

PROCESSING OF STEEL SLAG AS ROAD MAKING AGGREGATES

- Controlled Cooling
- Balling and Mechanical Breaking
- Primary Metal recovery
- Primary and Secondary Crushing
- Secondary Metal recovery
- Sizing/Screening in different sizes
- Weathering or Surface modification depending upon type of steel slag
- Stockpiling

Mineralogical Phase Analysis: Processed Steel Slag Aggregate





Calcite [%]	Brownmillerite [%]	Dolomite [%]	Larnite [%]	Srebrodolskite [%]	9015421 [%]	Wadsleyite [%]	Coesite [%]	Mn4 Al11 [%]
45.0	11.8	1.6	37.6	0.9	0.9	0.4	0.1	1.7

Chemical Composition: Processed Steel Slag Aggregates

Processed Steel Slag Aggregates	CaO (%)	SiO2 (%)	MgO (%)	Fe2O3 (%)	MnO (%)	SO3 (%)	P2O5 (%)	TiO2 (%)	K2O (%)	Cr2O3 (%)	Al2O3 (%)	L.O.I (%)
CONARC STEEL SLAG	40.2851	14.1681	3.53911	28.0370	1.84909	0.22997	0.85118	0.48389	0.08971	0.10463	5.39219	4.97
ELECTRIC ARC FURNACE	38.1911	15.3651	3.53323	30.4764	0.49035	0.20957	0.65264	0.49246	0.05804	0.10474	6.51654	3.91
BOF STEEL SLAG SOURCE 1	47.6821	9.1667	2.95467	15.8212	1.88333	2.6326	0.51588	0.47295	0.03933	0.08756	4.42357	14.32
BOF STEEL SLAG SOURCE 2	50.4881	10.2922	1.61494	15.8095	0.49843	0.3341	1.56345	0.69268	0.06449	0.12678	3.48972	15.03
BOF STEEL SLAH SOURCE 3	51.0419	10.1746	1.81634	17.7970	0.88432	0.40388	0.8988	0.41367	0.04088	0.04991	1.64881	14.83
NATURAL AGGREGATES	31.7181	33.1251	4.18127	6.6410	0.34606	0.2022	0.2045	0.6622	2.55524	0.03408	8.86008	11.47

INDIA'S FIRST ASPHALT STEEL SLAG ROAD: SURAT, GUJARAT

Success Story published by Australian Slag Association

INDIA'S FIRST 'SLAG ROAD' A RESOUNDING SUCCESS

In October 2021, India became the world's largest producer of crude steel. In the FY21, production of crude steel and finished steel stood at 102.49 million tonnes (MT) and 94.66 MT; and it's only meant to expand further. In the FY22, crude steel production in India is estimated to increase by 18%, driven by rising demand and education.

With predicted increases of production, means an increase in the amount of its by-product, slag. In past years, tonnes of slag have been stored as a waste product until recently when a new research project led to the first steel slag road in India's history.

The country's first steel slag road was finalised in the city of Surat, stretching across 1.2km of road, and consisting of 6 lanes. The now-famous road acts as a connectivity stretch for the Deepwater Hazira Port and connects to nearby highways. This stretch has been built by substituting natural aggregates with 100% processed steel slag aggregates in all layers of bituminous pavement. Considering its higher strength, the thickness of the road has also been reduced by 30%.

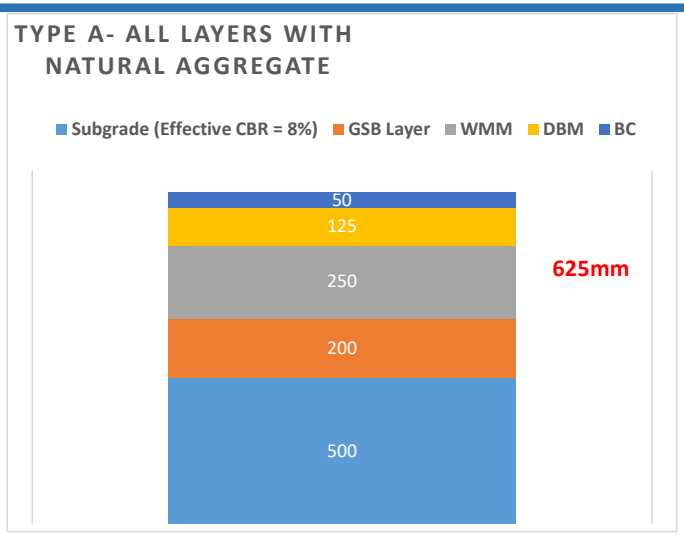
The successful implementation of the road is set to pave the way for the utilisation of more steel slag in upcoming projects, that would otherwise have been sitting in large mounds around the country. In addition, the use of slag is solving a nationwide shortage of virgin material that is consequently holding back the finalisation of various infrastructure projects.

The revolutionary project would not have been possible without intensive research conducted under the steel ministry. This research project was additionally sponsored by ArcelorMittal Nippon Steel under the technical guidance of the Central Road Research Institute (CSIR-CRRI) and has begun to change the way roads are constructed in India.

Almost a year from completion, Satish Pandey, principal scientist at CSIR-CRRI says the road is still upholding structural integrity. "Around 1,000-1,200 heavy commercial vehicles are using the road per day for the last one year and still it is performing well on different serviceability parameters. Around one hundred thousand tonnes of processed steel slag aggregates have been utilised in this project. We will soon come up with guidelines for widespread usage of processed steel slag in road and highway construction," he said.

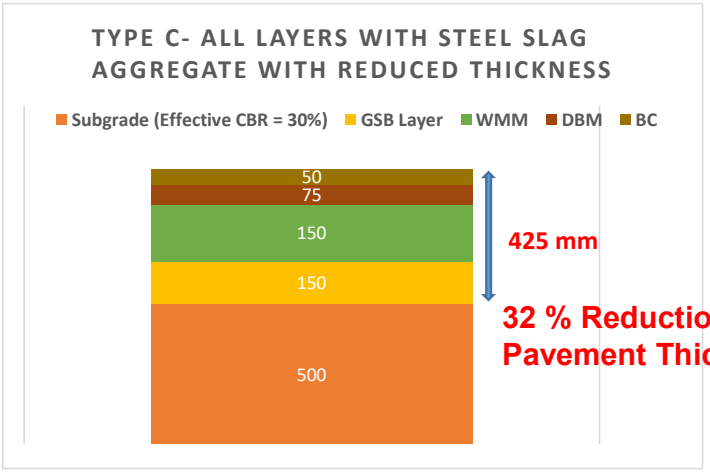
The future of slag in India is promising. Hopefully in the future, more projects like this one recognise the benefits of using slag to not only reduce waste, but to also improve the strength and durability of asphalt mixes in India.

Asphalt Steel Slag Road: Crust Composition

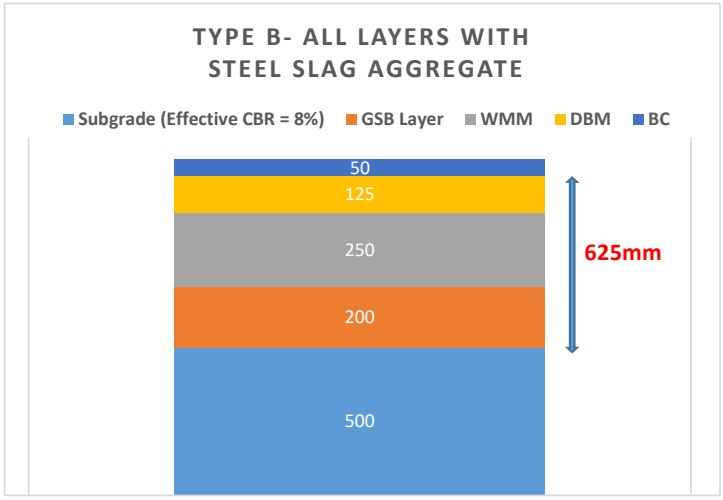


CONVENTIONAL ASPHALT ROAD

STEEL SLAG ROAD WITH REDUCED THICKNESS



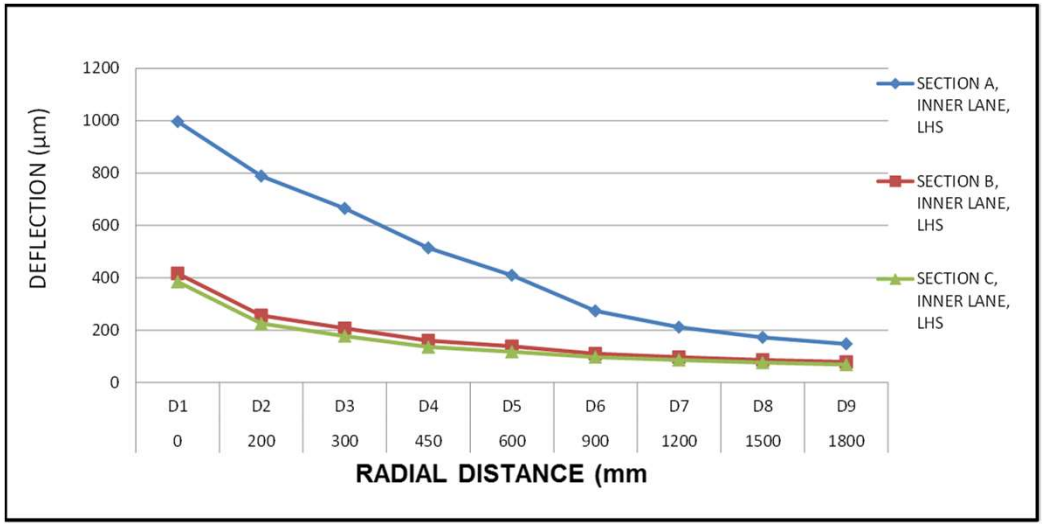
32 % Reduction in Overall Pavement Thickness



STEEL SLAG ROAD WITH CONVENTIONAL THICKNESS

Steel Slag Road: Comparative Structural Deflection

LHS SIDE, INNER LANE, AVERAGE DEFLECTION VALUES AT LOAD 140KN											
Description	Thickness in mm	Force	0 mm	200 mm	300 mm	450 mm	600 mm	900 mm	1200 mm	1500 mm	1800 mm
			D1	D2	D3	D4	D5	D6	D7	D8	D9
Section A, INNER LANE LHS (Control Section with Natural Aggregates)	BC+DBM = 175, WMM+GSB = 450, SUBGRADE = 500	140KN	996	789	665	514	410	273	211	172	147
Section B, INNER LANE LHS (Steel Slag in WMM, GSB, Subgrade)	BC+DBM = 175, WMM+GSB = 450, SUBGRADE = 500	140KN	416	256	207	160	138	110	97	86	78
Section C, INNER LANE LHS (Steel Slag in WMM, GSB, Subgrade)	BC+DBM = 125, WMM+GSB = 300, SUBGRADE = 500	140KN	385	226	178	136	117	97	86	76	69



India's First National Highway Steel Slag Road Section NH 66

- INDIA's First National Highway Steel Slag Road Section is built on NH 66 Mumbai Goa National Highway
- This is four lane road comprising Asphalt and Cement Concrete Steel Slag Road Sections
- Processed CONARC Steel Slag Aggregates are utilized as 100 % substitute of natural aggregates
- Around 80000 tonnes processed steel slag aggregates are utilized in the construction of road
- Slag Cement is utilized for construction of Cement Concrete steel slag road section
- Steel Slag aggregates are produced at JSW Steel Dolvi plant using customized steel slag valorisation technology developed by CSIR-CRRI

India's First Cement Concrete Steel Slag Road: Maharashtra

Steel Slag being tested to build national highways

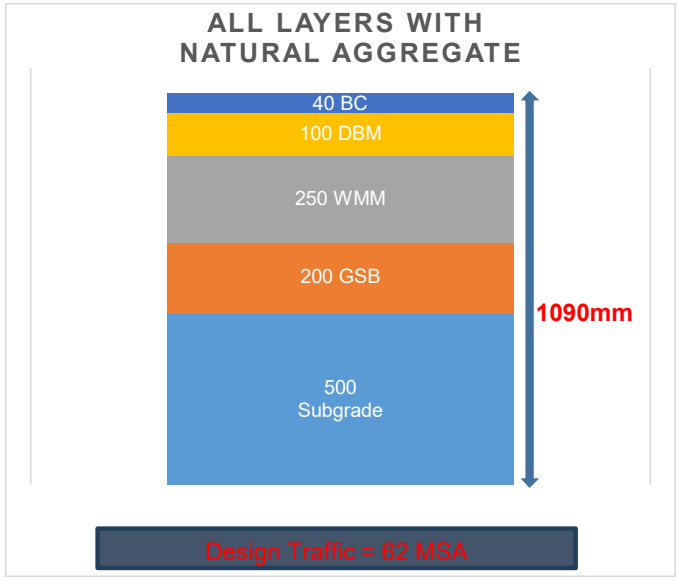
1 min read • Livemint

Updated: 15 Mar 2023, 07:26 PM IST

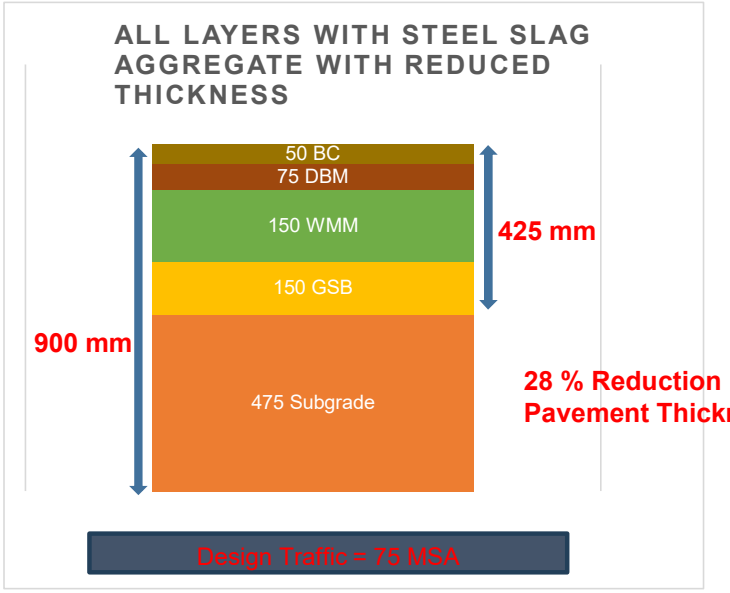
This initiative will help to address challenge of shortage of material used in development of the national highways, and could replace natural aggregates such as sand, gravel, or crushed stone with the waste material from the steel industry, road transport ministry said

The NHAI permitted CRRI to construct 1 km long trial patch in Raigarh district for PQC of Panvel – Indapur section of NH 66 near Mumbai where 100% natural aggregates were replaced by steel slag derived aggregates. The results from the trial have been encouraging.

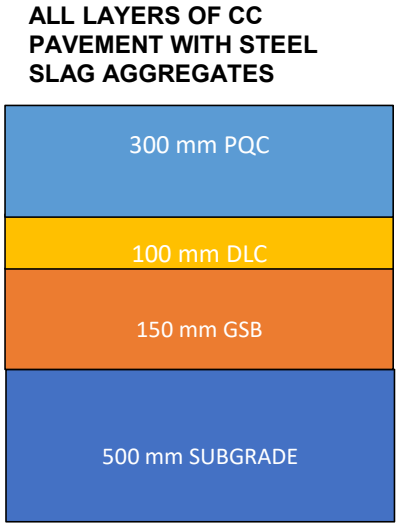
Asphalt Steel Slag Road: Crust Composition



CONVENTIONAL BITUMINOUS ROAD



BITUMINOUS STEEL SLAG ROAD



CEMENT CONCRETE STEEL SLAG ROAD

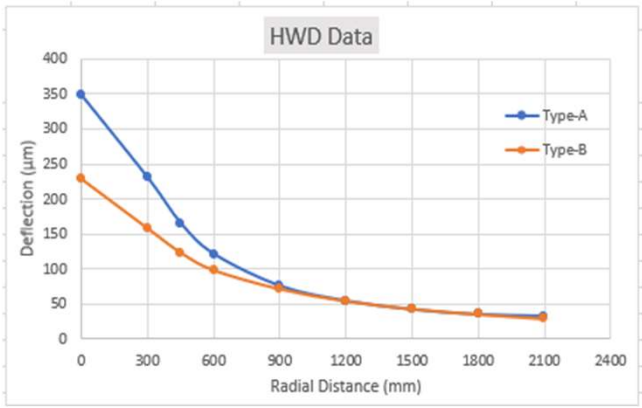
LAYING OF BITUMINOUS LAYER : Steel Slag Road NH-66

Treatment of Steel Slag Aggregates

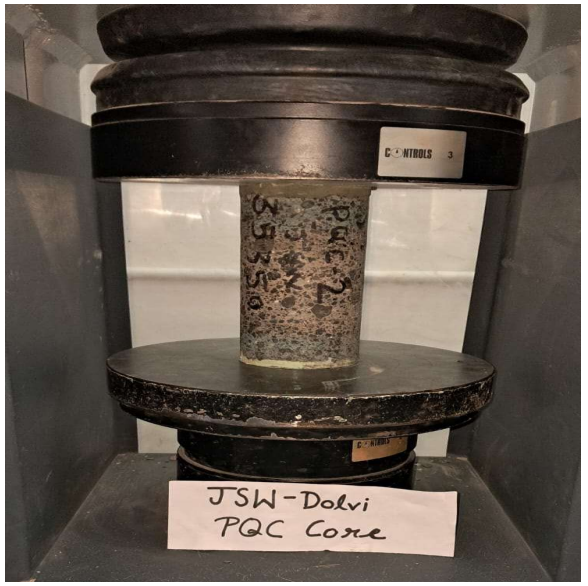
Production of Bituminous Mix

Structural Evaluation : Heavy Weight Deflectometer

Flexible Pavement Section HWD Data												
S.No.	Stree (kPa)	Load (kN)	D1 (µm)	D2 (µm)	D3 (µm)	D4 (µm)	D5 (µm)	D6 (µm)	D7 (µm)	D8 (µm)	D9 (µm)	Section
1	566	40	356	234	170	123	77	55	43	36	34	Type-A
2	566	40	351	233	166	123	77	55	42	35	33	
3	566	40	337	224	160	119	74	54	42	35	32	
Avg.	566	40	348	230	165	122	76	55	42	35	33	
4	566	40	229	159	124	99	71	54	43	34	28	Type-B
5	566	40	227	158	123	98	72	54	43	35	29	
6	566	40	231	158	124	99	72	55	43	37	30	
Avg.	566	40	229	158	124	99	72	54	43	35	29	



COMPRESSIVE STRENGTH TEST OF PQC CORE



PQC Core Test Results

Core No	Mass after Capping	Length after Capping			Diameter				Area	Volume	Appx. Density After capping)	Legnth/Diameter Ratio	Failer load	Comp. Strength	Correction Factor, F	Correct. C/S	Eq. Cube Strength
					D-1	D-2	D-3	Avg.									
	gm	mm	mm	Avg.	mm	mm	mm	mm	mm^2	mm^3	kg/m^3	X	KN	Mpa	Y	Mpa	Mpa
JSW/PQC-2	3706.4	192.27	192.16	192.22	94.30	94.32	94.07	94.23	6973.78	1340465.19	**2765.0**	2.0	295.4	42.36	1.00	42.54	**53.18**
JSW/PQC-3	4007.5	192.35	192.80	192.58	94.95	94.70	94.65	94.77	7053.44	1358316.57	**2950.3**	2.0	263	37.29	1.00	37.42	**46.77**

Steel Slag Road: High Altitude Border Areas

Niti Aayog Member Dr. Saraswat inspects Joram-Koloriang road

Steel slag road tech to be boon for BRO to build roads in border areas: Dr. Saraswat

ZIRO, Mar 27: Niti Aayog Member Dr. VK Saraswat said the CSIR-CRRI steel slag road technology will be a boon for the Border Roads Organisation (BRO) to build long-lasting heavy duty roads in strategic border areas.

Dr. Saraswat made the statement on the sidelines of the inspection of the 1-km stretch of pilot project steel slag road built by BRO at Joram-Koloriang road in Arunachal Pradesh along with a team of CSIR-Central Road Research Institute, Border Road Organization, Tata Steel and Lower Subansiri Deputy Commissioner Bamin Nime today.

Dr. Saraswat emphasized using alternative road materials like *(Cont. P.6)*

STEEL SLAG ROAD, JAMSHEDPUR, JHARKHAND: TATA STEEL

Processed BOF Steel Slag Aggregate in Granular Sub Base in NH-33

Processed BOF Steel Slag Aggregate in WMM in NH-33

MAJOR BENEFITS OF STEEL SLAG ROAD

- Reduction in overall Bituminous Road Thickness by 30 to 40 %
- Conservation of around 80000 tons of Natural Aggregates for construction of 1 Km six lane road
- Reduction in construction cost by 40 to 45 % in Bituminous and Cement Concrete Steel Slag Road
- Improved Durability of Road by 4 to 5 times
- Negligible Maintenance cost
- Reduction in Green House Gases Emission by 48 % by substituting natural aggregates with processed steel slag aggregates
- Cheaper, economical option of Natural Aggregates for Road Construction

WASTE TO WEALTH
Swachh Bharat Unnat Bharat

Appreciation from Hon. Prime Minister

STEEL SLAG ROAD BRO PROJECT: Infra creation and circular economy, both will get an impetus. Compliments to all those involved with this effort

AWARDS

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ENVIRO ANNOTATIONS NEW DELHI, 5th, May to 11th May, 2021 ISSUE NO. 2

CSIR-CRRI bags SKOCH Gold Award 2021 for Utilization of BOF Steel Slag in Road Construction

New Delhi: CSIR-Central Road Research Institute (CRRI) has received SKOCH Gold Award 2021 under Environment and Sustainability category for utilization of BOF steel slag of Tata steel Jamshedpur as substitute of natural aggregate in road construction. SKOCH Gold award has been conferred to CSIR-CRRI by eminent jury of Skoch group on 30th April 2021 for successfully converting applied research projects in to practices by facilitating the utilization of processed BOF steel slag aggregate in bituminous road construction.

Satish Pandey, Principal Scientist, CSIR-CRRI who lead the research studies has further informed us that the TATA Steel Jamshedpur sponsored two research projects to CRRI to explore possible utilization of BOF steel slag in road construction. According to an estimate around 150 to 200 kg. of steel slag is generated for 1 ton of carbon steel production. Tata Steel Jamshedpur plant which has annual steel production of 10 million ton per annum generates around 1.5-to-2-million-ton BOF steel slag per annum which largely considered as industrial waste material.

BOF Steel slag which cannot be used as such as road construction material owing to its vesicular structure and volumetric expansion characteristics has been successfully converted as road making aggregate using the steel slag processing methodology suggested by CRRI to Tata steel. Subsequently processed steel slag aggregate has been success fully utilized as 100 % substitute of natural aggregate in the construction of granular layers of NH-33 (passing from Jamshedpur city) under the supervision of CSIR-CRRI team. The periodic performance monitoring of this 1.5 km long test section was carried out be CSIR-CRRI for three years and test section found to be performing well on different test parameters.

Based on the research study TATA Steel branded the processed steel slag aggregate as TATA Aggreto and around 4 lakh ton of processed BOF steel slag aggregate so far has been supplied by Tata Steel for the construction of National, state highways and PMGSY roads in Jharkhand.

SKOCH GOLD AWARD SHARED WITH TATA STEEL MD, Shri T.V. Narendran

CSIR CRRI

Appreciation Letters

INDIA CHAPTER

CSIR CRRI

डॉ. वी.के. सारस्वत
Dr. V.K. Saraswat
सदस्य
Member
Tele : 23096566, 23096567
Fax : 23096603
E-mail : vk.saraswat@gov.in

सत्यमेव जयते

भारत सरकार
नीति आयोग, संसद मार्ग
नई दिल्ली - 110 001
Government of India
National Institution for Transforming India
NITI Aayog, Parliament Street,
New Delhi - 110 001

D.O. No.: 13(9)12015-Minerals **05th August, 2022**

Dear Dr Gokhale,

Subject: Appreciation for "**INDIA'S FIRST STEEL SLAG ROAD**" and Steel Slag Valorisation Technology Developed by CSIR-CRRI

I would like to congratulate the Council of Scientific & Industrial Research and Central Road Research Institute New Delhi to develop a technology for sustainable utilization of Steel Slag in the form of steel slag aggregates in road construction. The successful implementation of this technology for making the road aggregates has further underlined the NITI Aayog vision to spearhead environment-friendly sustainable infrastructure development in the nation using industrial waste materials.

India produces around 19 million tonnes of steel slag waste annually from various steel industries and this quantity is likely to increase multifold and is expected to reach 60 million tonnes by 2030. The majority of steel slag in absence of cost-effective technology and want of sustainable utilization mechanism ends as a solid waste dump in and around steel plants and becomes a source of land and air pollution.

I am very happy to mention that, having seen the **"Steel Slag Road" at Hazira Surat constructed by steel slag aggregates** under the CSIR-CRRI Technological supervision using processed steel slag aggregates of AMNS India, I am convinced to say that this technology has very good potential to develop the cost-effective, durable steel slag aggregates for road construction as a by-product for steel industries. it will not only be helpful for steel industries to make use of steel slag in the most productive way but also be helpful in curbing unsustainable quarrying of natural aggregate for road construction

I would also like to admire the dedication and devotion shown by CSIR-CRRI,R&D project team led by Shri Satish Pandey, Principal Scientist CSIR-CRRI for this scientific accomplishment to develop the technology for making steel slag aggregates for road construction and constructing **INDIA'S First Steel Slag Road"** at economical cost.

स्वच्छ भारत
एक कदम स्वच्छता की ओर

AM/NS INDIA

29th July 2022

Dr Rajesh S Gokhale.
Director General, CSIR and Secretary, DSIR
Anusandhan Bhawan,
2 Rafi Ahmed Kidwai Marg,
New Delhi – 110001

Subject: Commendable success of "**INDIA'S FIRST STEEL SLAG ROAD**" and Steel Slag Valorisation Technology Developed by CSIR-CRRI

Dear Sir,

I would like to place on record my deep appreciation to team CSIR-CRRI led by Shri Satish Pandey, Principal Scientist and Project Leader, CSIR-Central Road Research Institute for developing a cost effective, environment friendly, steel slag valorisation technology for conversion of EAF steel slag as road making aggregates. This technology not only help AMNS India for sustainable utilization of around 2 million tonnes of steel slag, generated annually in Steel Plant but also facilitates different road construction agencies to build a durable, green roads using processed steel slag aggregates at economical cost.

Around 1 Lakh tonnes of processed EAF steel slag aggregates developed at Hazira Steel Plant under the CRRI technological guidance has been successfully utilized in construction of "FIRST STEEL SLAG ROAD" at Surat by substituting natural aggregates.

This environment friendly Steel Slag Road technology for its novel scientific aspects received national and international acclaim and recently inducted in India Book OF Records and Asia Book of Records as "FIRST STEEL SLAG ROAD".

I am happy to bring it in your in attention that former Hon. Minister of Steel Shri R.C.P Singh and Member, Niti Aayog, Dr. V.K.Saraswat having inspected the steel slag road at Hazira Surat ,appreciated the technology and recommended its utilization for construction of national highway's in future.

Successful construction of Steel slag road is the testimony of collaborative painstaking efforts made by CSIR-CRRI and AMNS India team for this scientific accomplishment.

I am happy to inform you that the project has created a significant demand for processed steel slag aggregates and many road concessionaires of various NHAI projects are approaching AMNS India for steel slag aggregates.

TATA

T V Narendran
CEO & Managing Director

Mr Satish Pandey
Principal Scientist, Flexible Pavement Div.
Associate professor, AcSIR

Date : 19th September, 2022

Dear Mr Pandey,

It was a pleasure interacting with you during our meeting in Delhi, wherein we discussed the potential usage of industrial waste in steel making in different infrastructure applications.

We thank you and the CSIR-CRRI team for the support we received from you all in our sustainability journey.

I am happy to note that Border Road Organisation has decided to take a pilot project of building a 1 km long steel slag road near Itanagar, Arunachal Pradesh. I congratulate you on being inducted as an "Officer on Board" for providing technical guidance to the project.

I am keen that we work closely with you and support the above initiative. Our Industrial By-Product team, led by Mr Rajesh Kumar (Executive In-Charge, IBMD), whom you know, will take this forward and provide the necessary support as indicated in your letter.

I convey my thanks to the CSIR-CRRI team and wish you all the success in this upcoming project which will not only help us but also encourage sustainable steel slag utilisation in the steel industry.

With best regards,

T V Narendran

Technology Dissemination

Webinar on Steel Slag Road

Release of Scientific Documentary Movie on Steel Slag Road by India Science Channel of Vigyan Prasar, Govt. of India

THANKS FOR KIND ATTENTION

Satish Pandey

Principal Scientist

CSIR-Central Road Research Institute, New-Delhi

M: 9999366937, satishpandey.crri@nic.in