

CEMENT GROUTED BITUMINOUS MIX FOR LONGEVITY OF FLEXIBLE PAVEMENTS

Manoj Kr. Shukla

Senior Principal Scientist

Flexible Pavement Division



INTRODUCTION

The failures in Flexible Pavements are generally in the form of

Rutting

Fatigue Cracking

Moisture Induced



One of the technologies to yield *improved surfacing*
against
Moisture Induced Damages & Rutting is

**Cement Grouted Bituminous Mix (CGBM) for wearing
Course**

Cement Grout Bituminous Mix (CGBM)



Open Graded high voids (25-35%) Bituminous Mix



Filling Voids by Grouting with Cementitious Material

MATERIALS

Aggregates: Good quality aggregate with Specific Gravity more than 2.7

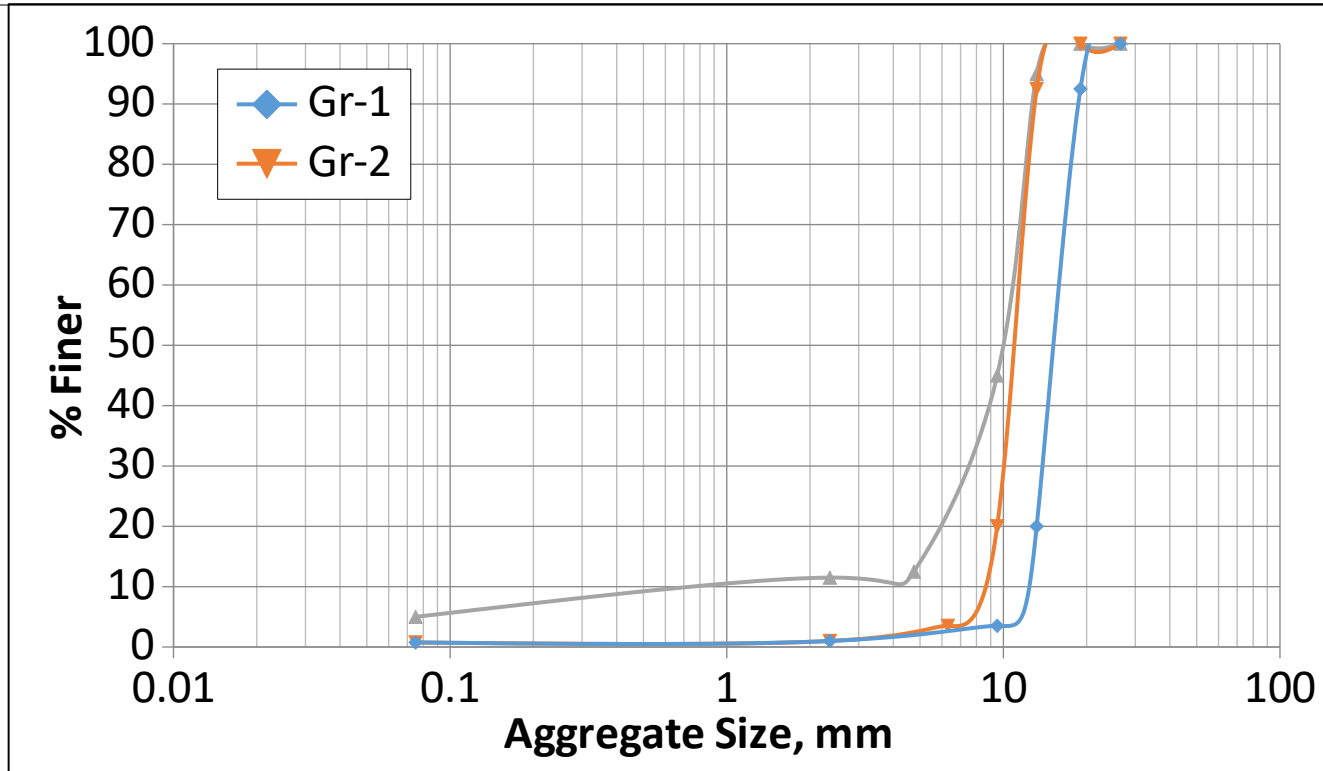
Bitumen: Viscosity Grade, typically VG30 / VG40

Grout: Blend of Cement , Sand, Fly ash, Micro silica, Superplasticizer, etc. or any suitable grout can be selected from such commercially available products.

Aggregate Properties	Test	Specification
Cleanliness	Grain Size Analysis	< 2 % passing 75 µm
Particle Shape	Combined Flakiness and Elongation Index	< 35 %
Strength	Los Angeles Abrasion Value	< 35 %
	Aggregate Impact Value	< 24 %
Polishing*	Polished Stone Value	> 55 %
Durability	Soundness (either Sodium or Magnesium) - 5 cycles	
	Sodium Sulphate	< 12 %
	Magnesium Sulphate	< 18 %
Water Absorption	Water Absorption	< 2 %

BITUMINOUS MIX DESIGN

Aggregate Gradation: Open Graded with dominance of Single Sized Aggregate to create 20 – 25 % Air Voids in Mix



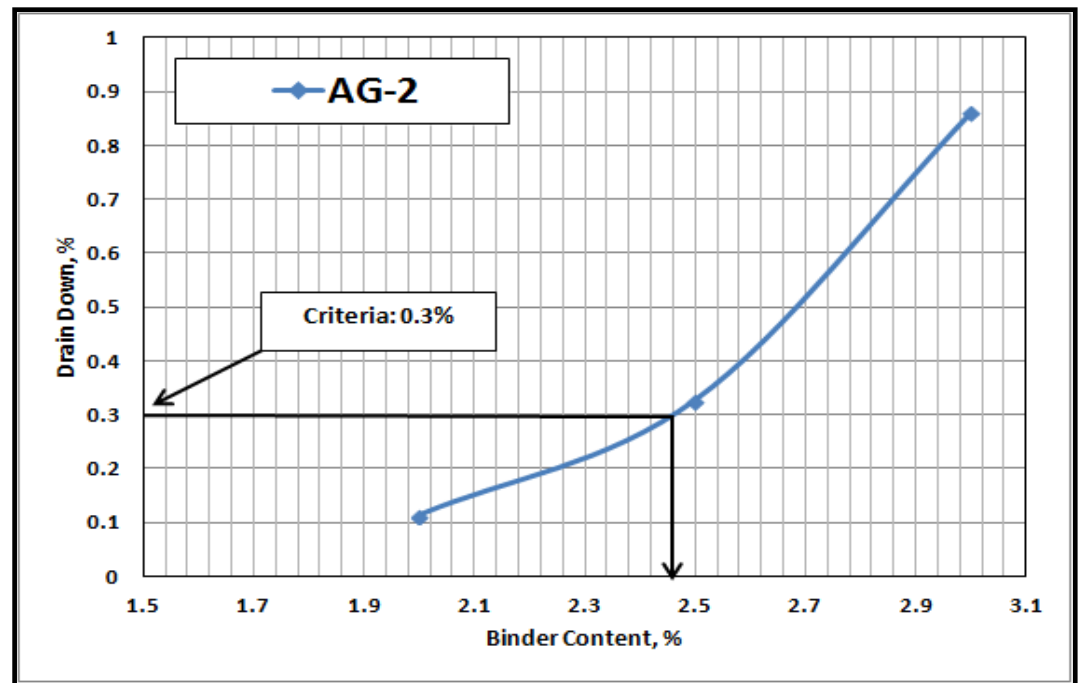
Optimum Binder contents

Type of binder used: VG 30

•Based on the Drain down test O.B.C. are determined for all selected gradations

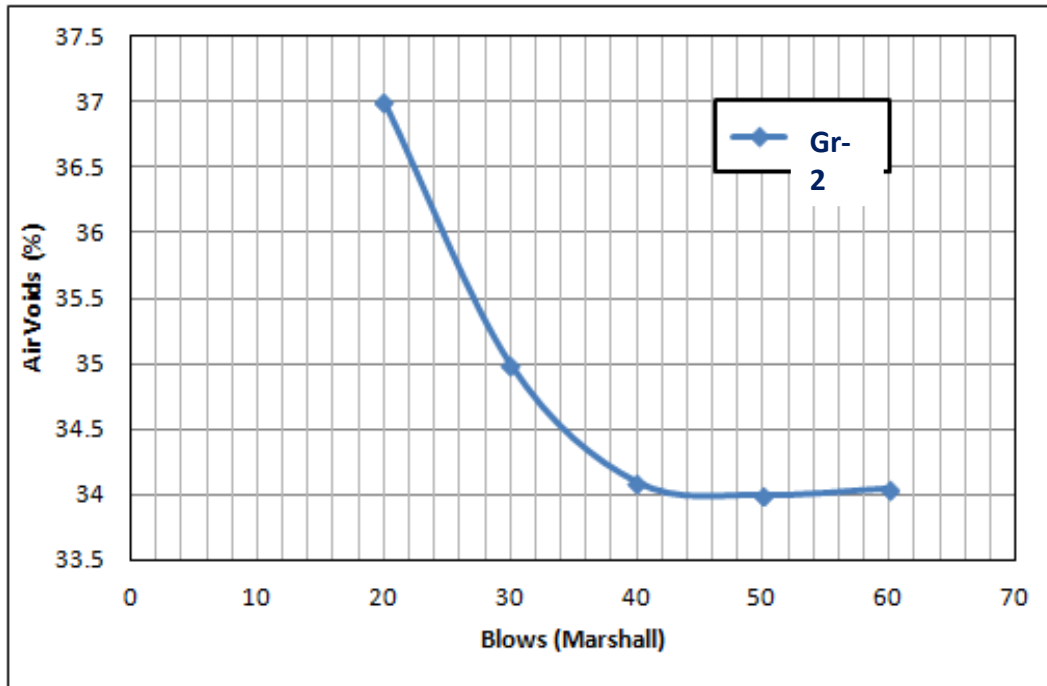


Drain Down
Apparatus



BITUMINOUS MIX DESIGN

Determining Compaction Effort: Air Voids reduction w.r.t. Compaction Effort

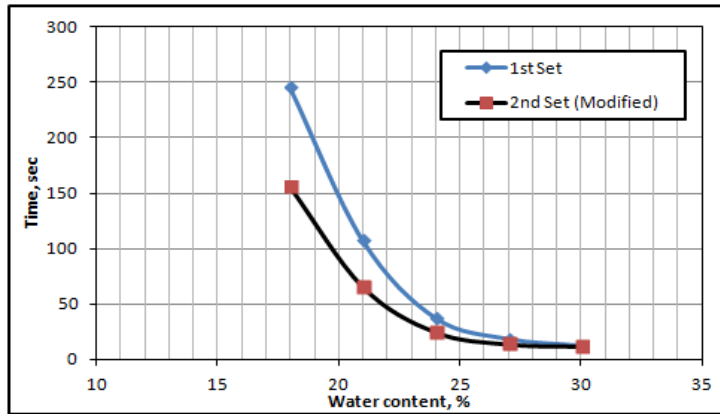


Air Voids vs. Number of Marshal Hammer Blows

40 blows are being suggested for Gradation I & II and 60 blows for Gradation III, all being applied on one face of the Marshall sample only



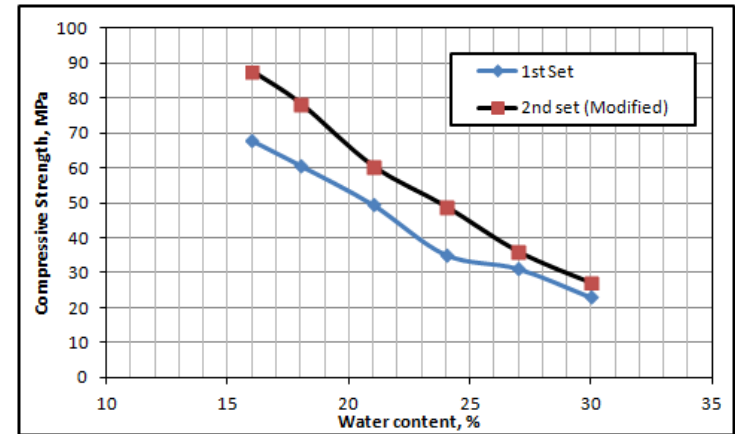
Consist of **Cement-Sand** blend with **Special additives**



Consistency for grout material



Marsh flow cone apparatus



7 days Compressive Strength

OPTIMIZATION OF GROUT

Fixing Water Content of Grout: Full Depth Penetration with Optimum strength

Grout

⇒ Consist of **Cement-Sand** blend with **Special additives**



Marsh Flow Cone apparatus

Grout Properties

Sufficient Flowability to achieve full depth penetration into the bituminous layer

Adequate Strength to achieve good composite properties



Partial Depth of grouting



[Lab Grouting.mp4](#)



Full Depth grouting

MIX DESIGN

- ✓ Compact Porous bituminous mix at target air voids for selected gradation & bitumen content
- ✓ Prepare grout at **different water** % (18 to 25%)
- ✓ Select optimum water content based on the **full depth grout** penetration in bituminous mix, while with maximum strength



Partial Depth of grouting



Full Depth grouting

BITUMINOUS MIX DESIGN

Sample preparation and testing: Finding Air Voids in Mix



Compacted Marshall Samples



Gr-I

Gr-III



Rice Apparatus for
calculating Theoretical
Maximum Specific Gravity
(G_{mm})



Marshall Compactor

GBM PRODUCTION

At Laboratory Scale

Laboratory Studies of CGBM.pptx



Compacted Marshall Samples



Cylindrical Sample



Beam Sample

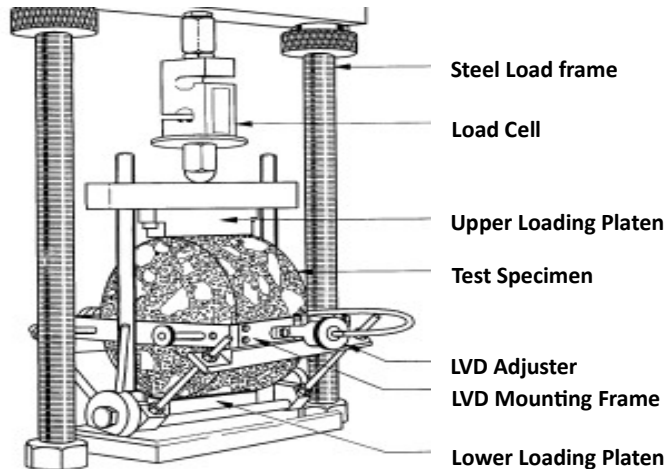


Grouted Bituminous Mix in Split Mould

MECHANICAL PROPERTIES OF CGBM

Resilient Modulus

Used as an input parameter for pavement analysis, design and evaluation



Loading Pulse : Haversine
 Temperature : 35° C
 Loading : 0.1s loading & 0.9s unloading
 Protocol : ASTM D 4123

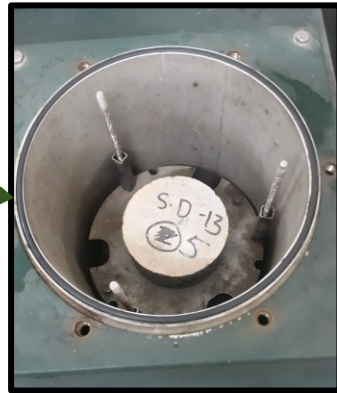
$$M_r = \frac{P * (\mu + 0.27)}{\Delta h * t}$$

P peak load
 μ poisons ratio
 Δh horizontal deformation
 t thickness

Type of Mix	Resilient Modulus, MPa @ 35° C
CGBM	15432
BC	2450

PERFORMANCE CHARACTERISTICS

Moisture Resistance : MIST



Pressure: 40 psi
Temperature: 60° C
Cycles: 3500

Mix Type	ITS, MPa @ 25° C		TSR, %
	Unconditioned Specimen	Moisture Conditioned Specimen	
CGBM	2.33	2.30	98.7
BC	0.99	0.81	81.8

MECHANICAL PROPERTIES OF CGBM

Modulus of Rupture and Compression Test

Mix Type	Modulus of Rupture, MPa	Compressive strength, MPa @ 35 °C
CGBM	1.8	5.4
BC	0.6	2.1



Modulus of Rupture
Test Set up in UTM

PERFORMANCE CHARACTERISTICS

Rutting: Wheel Tracking

- Wheel Tracker was used for evaluating rutting performance
 - Slab size: 30 cm x 30 cm
 - Testing Temperature : 60 °C
 - Repetitions : 20 000

For CGBM,

Rutting after 20000 passes: **0.26 mm**

For BC Mix,

Rutting after 20000 passes: **8 mm**



CGBM Construction at Field

- The following works need to be accomplished
- ✓ The existing bituminous surface is **cleaned**.
 - ✓ Emulsion or bitumen is spread over it as **tack coat**.
 - ✓ Layer of open graded hot **high void bituminous mix** is then laid using the paver and compacted with smooth wheeled roller.
 - ✓ Once the compacted bituminous surface **cools down to ambient** temperature, the requisite quantity of **cementitious grout material** mixed thoroughly with water (mixed using Pan mixer or other suitable blending equipment) can then be poured and spread uniformly over bituminous surface.

Pavement Construction at Field

- ✓ Grout should automatically flow into the voids due to **gravity** and its flowability.
- ✓ **Sweeping/Squeezing** or other such simple techniques (mechanized process) can be adopted to accelerate the process of grout penetration. This exercise also avoids formation of thin layer of grout over the bituminous surface.
- ✓ The grouted surface is allowed to set for **one day** and then opened for traffic. However, the section is cured by light sprinkling of water which is to be practiced for 3 days.

SELECTED SECTIONS



SD Jain College Road, Surat



TP Road, Surat (100 m)

CGBM CONSTRUCTION



Pavement Construction at Field



[Field Grouting.mp4](#)

FINISHED SURFACE (AFTER 2 DAYS OF CONSTRUCTION)



**SD Jain College
Road**



**TP Nagar
Road**



View of two Sections after 6 Months



CGBM SURFACE



after two months



after six months



after one year

CGBM section after 5 Mansoon



CGBM FIELD CORES



**Middle Core shows the bottom
of CGBM Layer Surface**

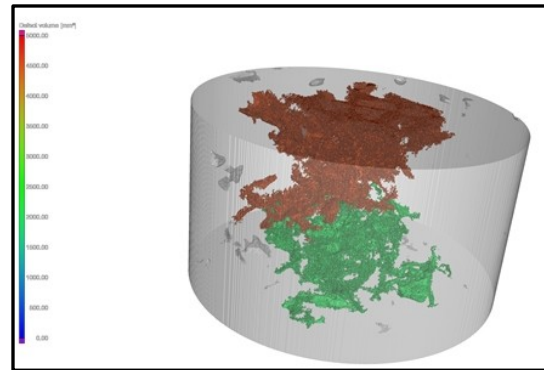
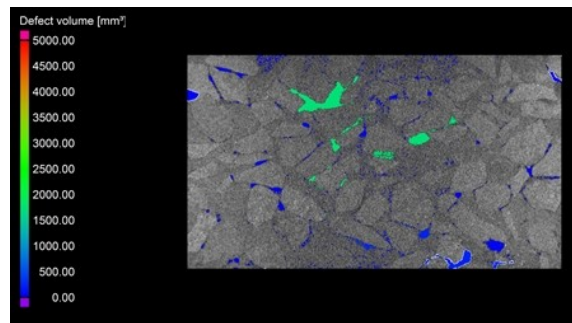
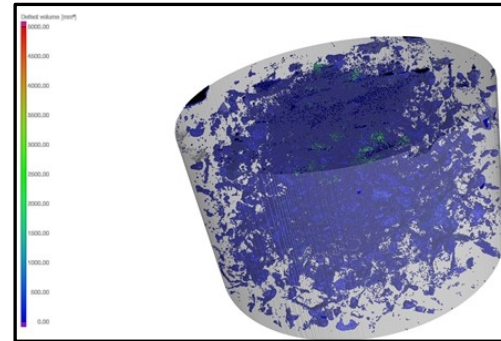
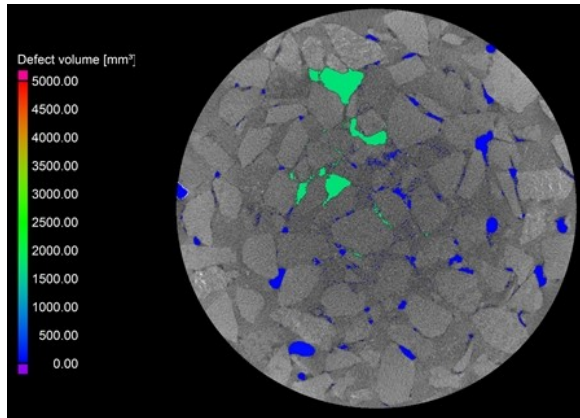


**Top surface
(Core taken from Pavement)**



**Side View of core taken from
pavement showing full depth grout**

Micro-CT Images



Air voids is 2.59%

The Air voids volume have been marked with different colours with varying range

EVALUATION ON FIELD CORES

SD Jain Road, Surat (100 m)

Average Values (3 Samples)	Curing Period Days	Density (g/cc)	ITS, MPa	Resilient Modulus, MPa		
			25°C	25°C	35°C	45°C
SD Jain Road, Surat (100 m)						
Average Values (3 Samples)	7	2.476	1.58, MPa	18000	15072	10000
	Curing Period Days	(g/cc)	25°C	25°C	35°C	45°C
	7	2.490	1.56	19200	16200	12500

FWD Data Analysis

Pavement Layers	Moduli Values (MPa)	
	As per Convention Before laying of CGBM	Back Calculated using FWD Data After laying of CGBM
Bituminous surface	1365	9800
Granular layer	230	260
Subgrade	26	26

IRC GUIDELINES FOR CGBM IRC SP 125-2019

Requirements of Cement Grouted Bituminous Mix – Material Requirements

Sr. No.	Properties	Units	Test Method	Recommended Values for CGBM
1	Aggregate/Binder			
1.1	Aggregate grading	-	-	CGBM Gr-I, Gr-II, Gr-III or Any other grading giving 25-35% voids
1.2	Air Voids	%	ASTMD3203	25-35
1.3	Binder content	%	ASTM D6390	As per drain down test or min. 3.25%*
2	Grout Material (Formulated or Commercially available grout)			
2.1	Grade of Cement	-	IS 269-2015	OPC 43 or OPC 53
2.2	Flyash specification	-	IS 3812 part 2 (min. 65 % passing 45 micron)	Flyash for concrete application
2.3	Properties of grout			
2.3.1	Initial Setting Time	Hrs	IS 4031 Part 5	4-5
2.3.2	Final Setting Time	Hrs	IS 4031 Part 5	6-10
2.4	Characteristic Compressive Strength @28 days	N/mm ²	ASTM C109 (size 50*50*50 mm)	40-100
2.5	Flexural strength at 28 days	N/mm ²	IS 4031 Part8 (sample size-160*40*40)	5-7
2.6	Fluidity ASTM C 939	sec	ASTM C 939	20-50

IRC GUIDELINES FOR CGBM IRC SP 125-2019

Requirements of Cement Grouted Bituminous Mix – Material Requirements

Sr. No.	Properties	Units	Test Method	Recommended Values for CGBM
3	CGBM Composite			
3.1	Voids in CGBM @ 7 days	%	ASTM D3203	2-3
3.2	Full depth grouting	%	Visual	97-100
3.3	Compressive strength at 28 days	N/mm ²	ASTM C39 (100mm dia. & 200 mm ht.)	>5
3.4	Resilient Modulus @ 28 days, 35°C	N/mm ²	ASTM D4123	> 10000**
3.5	Flexural strength @ 28 days	N/mm ²	ASTM C78 (Beam size 180*60*60 mm)	min. 2.0
3.6	Marshal Stability @ 28 days, 60°C	kN	ASTM D6927	min. 60
3.7	Indirect tensile strength @28 days, 35°C	N/mm ²	ASTM D6931	min. 1.0
3.8	Retained ITS strength at 28 days	%	AASHTO T283	97
3.9	CGBM layer thickness	mm	-	40-50 for traffic > 5 MSA 30 for traffic up to 5 MSA
3.10	Opening to traffic	-	-	After 24 hrs for light traffic Requirement can be specified by user
3.11	Skid resistance	BPN	ASTM E303	> 55

Life Cycle Cost Analysis

**Initial Construction Cost of BC 40 mm
Thick = Rs. 450-480 /sqm**

**Initial Construction Cost of PMC 25 mm
Thick = Rs. 300 /sqm**

Life expectancy of BC/PMC is 3-5 years

Vs

**Initial Construction Cost of CGBM 40 mm
thick = Rs. 550/sqm**

Life expectancy 7-8 years

Advantages of CGBM

- ✓ **Impermeability** & Resistance against **Moisture Induced Damages and** Resistance to **Permanent Deformation**
- ✓ Higher **Flexibility** & **Absence of joints** in comparison to Rigid Pavements
- ✓ High static bearing capacity and distribution of stress
- ✓ **Lower Thermal Susceptibility**
- ✓ Good **Skid Resistance**

Application of Grouting

- [Lab Grouting.mp4](#)
- [Field Grouting.mp4](#)
- [CGBM Preparation&Laying.mp4](#)

THANK YOU ALL

For Further Queries Pls contact

manojshukla1307@gmail.com