Influence of Mica in Manufactured Sand on Cement Mortar: Mineralogical and Mechanical Behaviour

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Abstract: Manufactured sand (M-sand) has emerged as a viable substitute for natural river sand in cement mortar applications. This study investigates the influence of mica content and mineralogical composition of M-sand sourced from six quarries in Karnataka, India, on expansion/contraction behaviour and compressive strength of cement mortar. Petrographic thin-section analysis and grain-size mineral counting were conducted on samples from quarries at Kotagal, Vishnupriya (Schoolagiri), Muddenahalli, Tekal, Peresandra, and Gudibande. An Accelerated Mortar Bar Test (AMBT) per IS 2386 Part VII was performed on 132 mortar bar specimens (25 × 25 × 285 mm) at mix ratios of 1:1 and 1:2.25 immersed in 1N NaOH at 80°C for 14 days. Compressive strength of 70.6 mm mortar cubes was evaluated at 28 days. Results reveal that mica content is the dominant factor governing volumetric instability: the sample with highest mica content (MS-Kotagal, 25%) exhibited greatest expansion (1.82 mm) and contraction (1.75 mm), while natural sand (9.17% mica) showed best dimensional stability. Compressive strength ranged from 48.56 N/mm² (MS-Kotagal) to 55.64 N/mm² (MS-Tekal), confirming the adverse effect of mica on mortar strength. These findings provide practical guidelines for selecting M-sand in plastering and masonry mortar applications.

Keywords: *Manufactured Sand; Cement Mortar; Mica Content; Petrographic Analysis; Accelerated Mortar Bar Test; Alkali-Silica Reaction; Compressive Strength.*

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I. INTRODUCTION

The rapid growth of the construction industry worldwide has significantly increased demand for fine aggregates in cement mortar production. Natural river sand, traditionally the primary fine aggregate, is becoming increasingly scarce due to unrestricted mining, environmental regulations, and rising transportation costs. Manufactured sand (M-sand), produced by mechanically crushing granite and similar hard rocks, has emerged as the most practical and sustainable alternative [1].

Cement mortar is a fundamental construction material used extensively for plastering, masonry bonding, waterproofing, and repair applications. Its performance depends not only on the water-cement ratio and curing conditions but critically on the mineralogical and physical characteristics of the fine aggregate used. Unlike natural river sand—geologically processed and mineralogically uniform—M-sand retains the full mineral assemblage of the parent rock, including potentially deleterious constituents such as mica [2].

Mica is a phyllosilicate mineral commonly present in granite-derived M-sand. Its platy morphology and high water absorption capacity increase water demand in mortar mixes, weaken the aggregate-paste interfacial transition zone, and promote volumetric instability through swelling and shrinkage. While IS 383 specifies zoning criteria for grading, the broader impact of mica on mortar dimensional behaviour remains inadequately studied for Indian granite-sourced M-sand [3].

The Alkali-Silica Reaction (ASR) represents another potential concern in M-sand mortars. Reactive silica polymorphs—microcrystalline quartz, strained quartz—can react with alkali hydroxides in cement pore solution to produce an expansive gel causing cracking and deterioration [4]. The Accelerated Mortar Bar Test (AMBT) per IS 2386 Part VII provides a standardized 14-day protocol for evaluating aggregate reactivity potential.

This paper presents a comprehensive experimental investigation into the influence of mineralogical composition, particularly mica content, of M-sand from six quarries in

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Karnataka on: (i) expansion and contraction behaviour of mortar bars under AMBT conditions; and (ii) 28-day compressive strength of mortar cubes.

II. LITERATURE REVIEW

Xing et al. [2] investigated varying mica levels in manufactured sand mortar and demonstrated that increasing mica content reduces compressive strength at both 28 and 60 days; SEM analysis showed a less dense microstructure with micro cracks at higher mica contents. Cepuritis et al. [5] studied crushed aggregate fines from 10 Norwegian quarries and established that rheological behaviour of cement paste is governed primarily by specific surface area and surface properties of fines.

An et al. [6] reported that aggregate mineralogy significantly influences the coefficient of thermal expansion (CTE) of concrete, with CTE increasing 7.9–9.7 με/°C with higher silicon content, making specimens more susceptible to thermal cracking. Praveen Kumar et al. [7] studied M-sand concrete with varying fines content (0–20%) and found that 5% fines produces optimum strength and durability properties.

On ASR behaviour, Shon et al. [9] established that mortar bar expansion is directly proportional to water-cement ratio and NaOH concentration, with Class F fly ash effectively reducing expansion. Lin et al. [10] found optimal SCM replacement levels of 30% fly ash, 20% silica fume, and 5% slag for ASR mitigation in granite-derived aggregates. Boyd-Weetman et al. [11] confirmed that ASR expansion increases clearly with alkali concentration (0.4–1.0 M NaOH) in the AMBT. These studies collectively highlight the critical role of aggregate mineralogy in mortar performance.

III. MATERIALS AND EXPERIMENTAL PROGRAMME

➢ *Materials*

Ordinary Portland Cement (OPC) 53 Grade conforming to IS 12269 was used throughout. Table I summarises cement properties verified per IS 4031.

Table 1 Physical Properties of OPC 53 Grade Cement

Sl.	Property	IS Code	IS Limit	Observed
1	Specific Gravity	IS 4031-Pt.11	3.15	3.125
2	Fineness (% retained on 90μm)	IS 4031-Pt.1	< 10%	4%
3	Soundness (Le Chatelier)	IS 4031-Pt.3	< 10 mm	4 mm
4	Initial Setting Time	IS 4031-Pt.5	≥ 30 min	45 min
5	Final Setting Time	IS 4031-Pt.5	≤ 600 min	570 min

Fine aggregates comprised six M-sand samples from quarries across Karnataka and one natural river sand (NS) as control (Table II). All aggregates were tested per IS 383 for specific gravity and sieve analysis. Potable water and 1N NaOH solution (40 g/L) were used for mortar preparation and AMBT, respectively.

Table 2 Fine Aggregate Sources and Basic Properties

Code	Source	Type	Sp.Gr.	Zone (IS 383)	Mica (%)	GPS Coordinates
KM	MS-Kotagal	M-Sand	2.73	Zone-II	25.0	13.614°N / 77.783°E
VP	MS-Vishnupriya	M-Sand	2.62	Zone-II	21.7	12.812°N / 78.019°E
MD	MS-Muddenahalli	M-Sand	2.75	Zone-II	18.3	13.405°N / 77.673°E
TK	MS-Tekal	M-Sand	2.62	Zone-II	20.0	13.002°N / 78.024°E
PR	MS-Peresandra	M-Sand	2.78	Zone-III	15.0	13.610°N / 77.785°E
GB	MS-Gudibande	M-Sand	2.70	Zone-II	17.5	13.672°N / 77.670°E
NS	Natural Sand	River Sand	2.58	Zone-III	9.2	13.390°N / 78.026°E

➢ *Petrographic and Mineral Analysis*

Thin-section specimens (30 × 30 mm, 30 μm thick) were prepared from coarse aggregate rock samples collected at each quarry. Specimens were cut using a diamond saw, polished with progressively finer silicon carbide abrasives, mounted on glass slides with epoxy resin, and examined under an Olympus MX40 polarizing microscope at the Department of Applied Geology, Kuvempu University, Shivamogga. Modal analysis (point counting) was performed using ImageJ software to quantify mineral percentages.

Grain-size mineral analysis of the fine aggregate fraction was conducted by optical counting to determine quartz, feldspar, mica, and olivine proportions. Results are presented in Tables III and IV.

➢ *Accelerated Mortar Bar Test (AMBT)*

Mortar bars (25 × 25 × 285 mm) were cast in steel moulds per IS 2386 Part VII at binder-to-aggregate ratios of 1:2.25 and 1:1, with w/b of 0.47 and 0.50 respectively, yielding 132 specimens. After demoulding at 24 h, bars were immersed horizontally in 1N NaOH at 80 ± 2°C in covered trays for 14 days. Dimensional measurements (length, width, depth) were taken at 1 h, 2 h, 4 h on Day 1, then at 24-h intervals using a digital vernier calliper (0.02 mm accuracy).

➢ *Compressive Strength*

Mortar cubes (70.6 × 70.6 × 70.6 mm) were prepared at 1:2.25 mix ratio per IS 4031 Part 6. Cubes were water-cured for 28 days and tested on a Universal Testing Machine; three cubes per sample were averaged.

IV. RESULTS AND DISCUSSION

➢ *Mineral Composition*

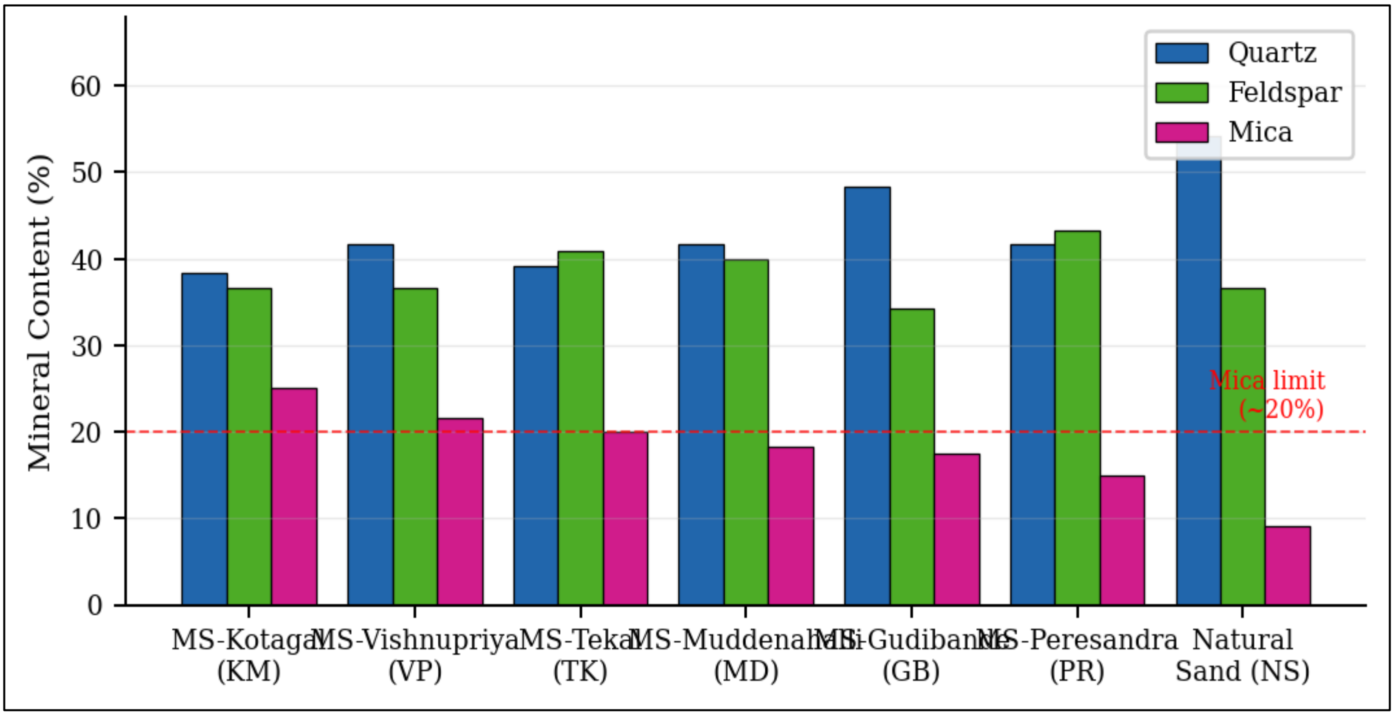

Fig 1 Grain-Size Mineral Composition of M-Sand and Natural Sand Samples

Table 3 Modal Analysis of Coarse Aggregate Rock Samples (% by area)

Sample	Qtz.	Plag.	Sericite	K-Fsp	Biotite	Hbl.	Chlorite	Musc.	Opaque	Others	Rock Type
MS-1 (TK)	35	19	4	16	12	9	2	2	0.2	0.8	HBG
MS-2 (KM)	35	19	4	16	12	9	2	2	0.2	0.8	HBG
MS-3 (VP)	32	22	—	27	4	13	—	—	—	2	HBG
MS-4 (MD)	31	23	—	26	5	14	—	—	—	4	HBG
MS-5 (PR)	32	22	—	27	12	4	—	—	—	3	BG

HBG = Hornblende-Biotite Granite; BG = Biotite Granite

Table 4 Grain-Size Mineral Analysis of Fine Aggregate (% by count)

Sample	Quartz (%)	Feldspar (%)	Mica (%)	Olivine (%)
MS-Kotagal (KM)	38.33	36.67	25.00	0
MS-Vishnupriya (VP)	41.67	36.67	21.67	0
MS-Muddenahalli (MD)	41.67	40.00	18.33	0
MS-Tekal (TK)	39.17	40.83	20.00	0
MS-Peresandra (PR)	41.67	43.33	15.00	0
MS-Gudibande (GB)	48.33	34.17	17.50	0
Natural Sand (NS)	54.17	36.67	9.17	0

Quartz is the most predominant mineral in all samples (average 43.14%), contributing to hardness and abrasion resistance. Feldspar is present in considerable quantities (average 38.05%), improving angularity and bonding. Mica content ranges from 9.17% (NS) to 25.0% (KM); only MS-Kotagal slightly exceeds the commonly recommended 20% limit. Olivine is absent in all samples, confirming non-mafic, granite-type source rock.

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➢ *AMBT Expansion and Contraction Behaviour*

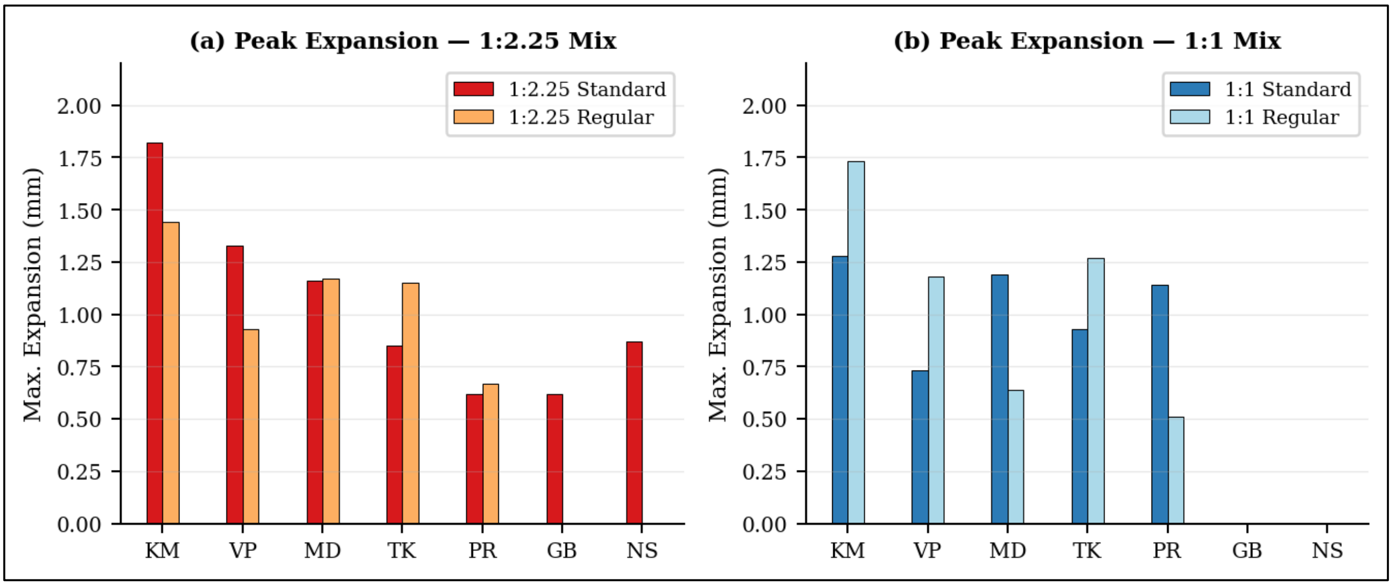

Fig 2 Peak AMBT Expansion Comparison Across All Samples and Mix Ratios

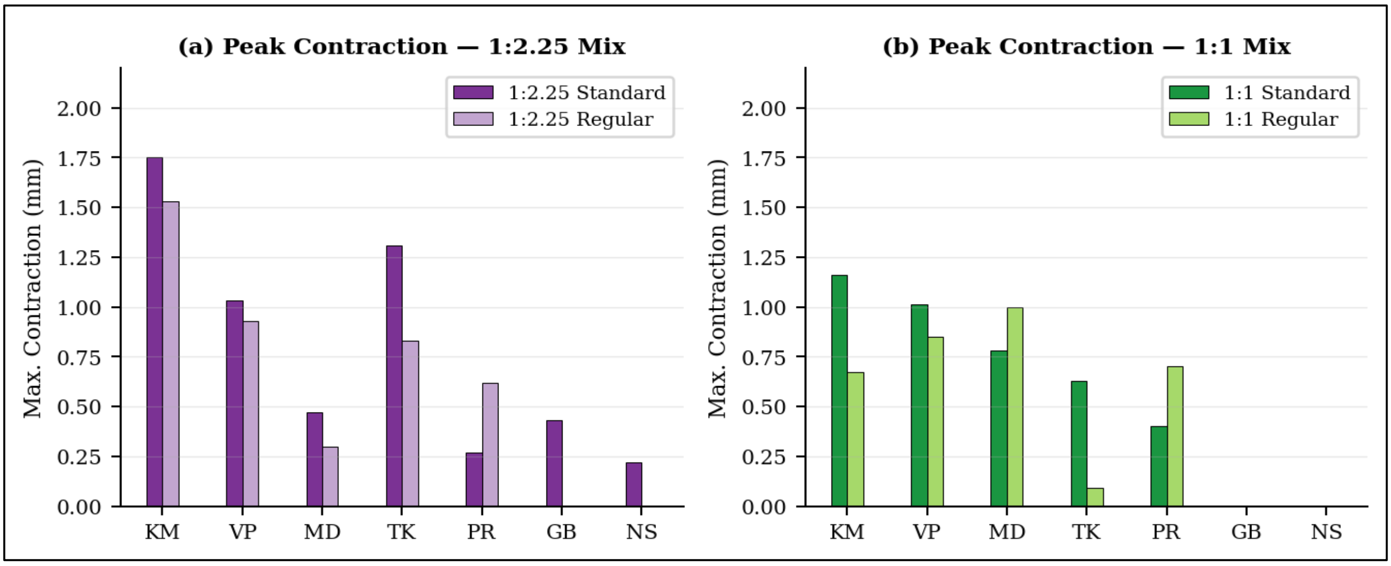

Fig 3 Peak AMBT Contraction Comparison Across All Samples and Mix Ratios

Table 5 Peak AMBT Expansion and Contraction Summary

Ref.	Sample	Mix Ratio	Max Exp.(mm)	Day	Max Cont.(mm)	Day	Mica (%)
KL-1	MS-Kotagal	1:2.25 (Std)	1.82	10	1.75	13	25.0
KL-2	MS-Kotagal	1:1 (Std)	1.28	3	1.16	3	25.0
KL-3	MS-Kotagal	1:2.25 (Reg)	1.44	8	1.53	4	25.0
KL-4	MS-Kotagal	1:1 (Reg)	1.73	8	0.67	7	25.0
VP-1	MS-Vishnupriya	1:2.25 (Std)	1.33	10	1.03	7	21.7
VP-2	MS-Vishnupriya	1:1 (Std)	0.73	3	1.01	5	21.7
MD-1	MS-Muddenahalli	1:2.25 (Std)	1.16	13	0.47	13	18.3
MD-2	MS-Muddenahalli	1:1 (Std)	1.19	7	0.78	2	18.3
TK-1	MS-Tekal	1:2.25 (Std)	0.85	2	1.31	11	20.0
TK-4	MS-Tekal	1:1 (Reg)	1.27	9	0.09	5	20.0
PR-1	MS-Peresandra	1:2.25 (Std)	0.62	1	0.27	7	15.0
PR-2	MS-Peresandra	1:1 (Std)	1.14	12	0.40	12	15.0
GB-1	MS-Gudibande	1:2.25 (Std)	0.62	8	0.43	1	17.5
NS	Natural Sand	1:2.25 (Std)	0.87	4	0.22	10	9.2

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MS-Kotagal (25% mica) consistently exhibited the highest expansion and contraction across all four mix ratios, with peak expansion reaching 1.82 mm at Day 10 (KL-1). The 1:2.25 mix generally produced greater volumetric changes than 1:1, attributable to the higher aggregate-to-binder ratio concentrating the influence of aggregate mineralogy. MS-Peresandra (15% mica) and Natural Sand (9.17% mica) displayed the most stable behaviour.

Width and depth changes (6–8% for high-mica samples) exceeded length changes in all specimens, indicating preferential swelling perpendicular to the bar axis—attributed to the platy orientation of mica flakes parallel to the casting face. The pattern of initial expansion followed by contraction is consistent with dual mechanisms of ASR gel swelling and subsequent moisture loss/self-desiccation at 80°C.

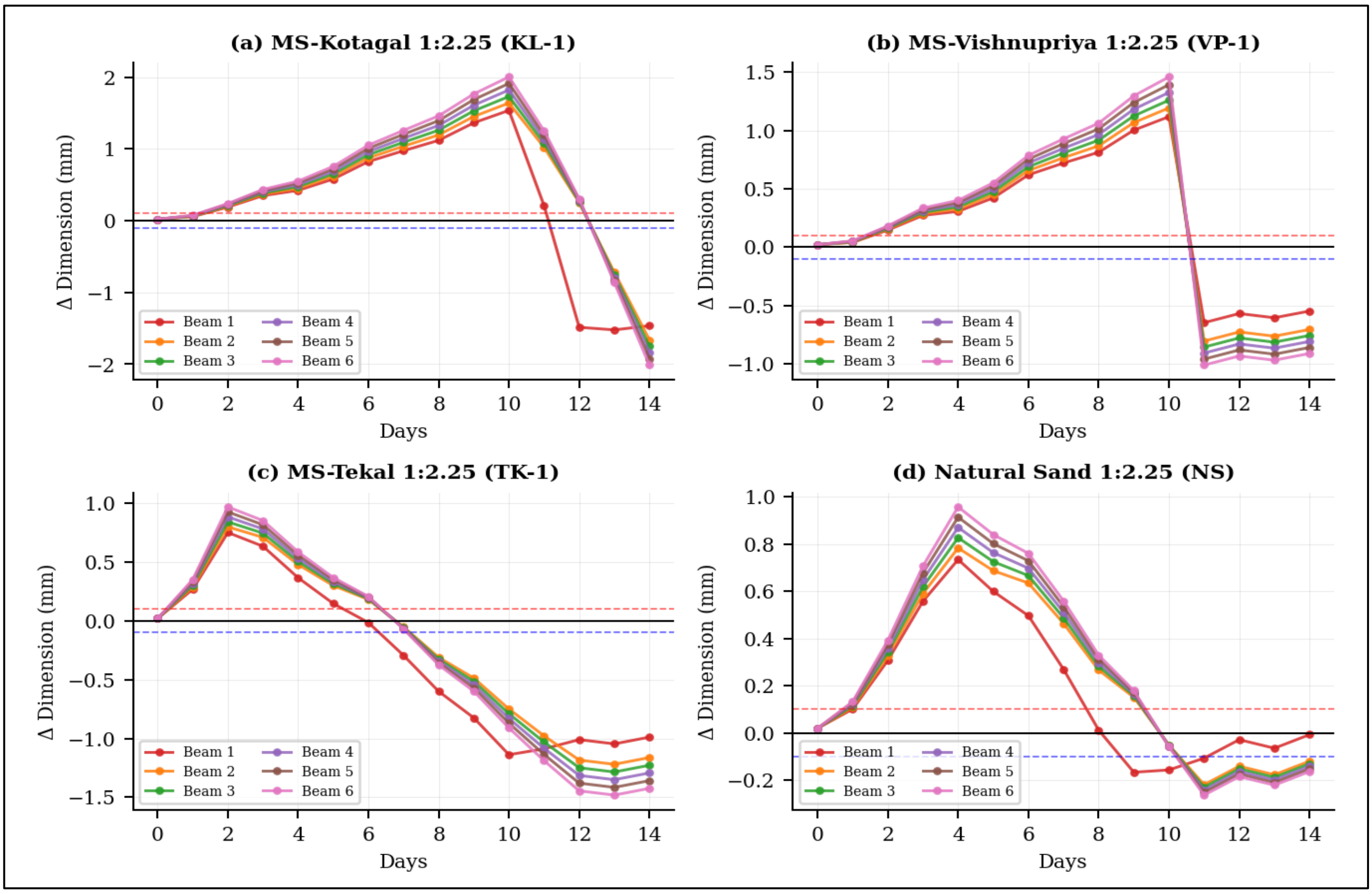

Fig 4 Representative AMBT Dimensional Change Profiles (1:2.25 Standard Mix, 6 Beams per Sample)

➢ *Compressive Strength*

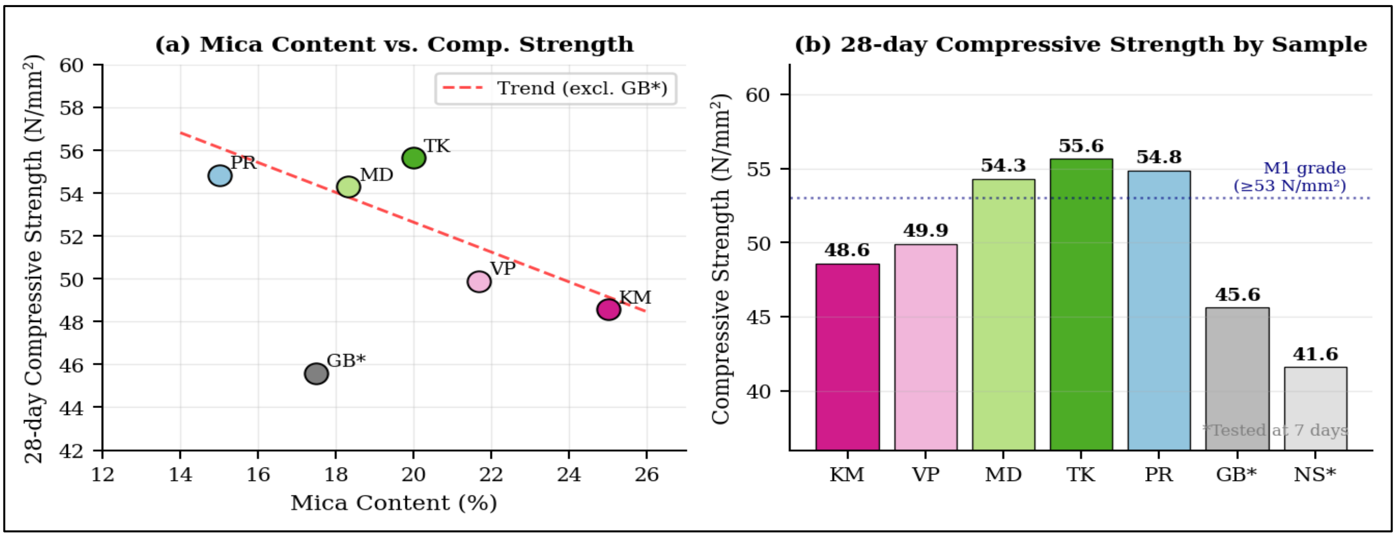

Fig 5 Compressive Strength Results and Correlation with Mica Content

Table 6 28-Day Compressive Strength of Mortar Cubes (1:2.25 Mix Ratio)

Sample	Mica (%)	Avg. Load (kN)	X-sec. Area (mm²)	Strength (N/mm²)	Remarks
MS-Kotagal (KM)	25.0	242.0	4984.36	48.56	Lowest
MS-Vishnupriya (VP)	21.7	246.7	4984.36	49.88	—
MS-Muddenahalli (MD)	18.3	270.7	4984.36	54.30	—
MS-Tekal (TK)	20.0	277.3	4984.36	55.64	Highest
MS-Peresandra (PR)	15.0	273.3	4984.36	54.83	—
MS-Gudibande (GB)*	17.5	227.3	4984.36	45.60	7-day
Natural Sand (NS)*	9.2	207.3	4984.36	41.59	7-day

* Tested at 7 days. Strength values are not directly comparable with 28-day results.

The strength reduction with increasing mica is attributed to: (1) the high water demand of mica's large specific surface area increasing the effective w/c ratio, reducing paste strength; and (2) poor bond between platy mica surfaces and cement paste creating preferential failure planes. A 7% increase in mica content (KM vs. TK) corresponds to approximately 12.8% reduction in 28-day compressive strength.

- *Performance Comparison — Radar Analysis*

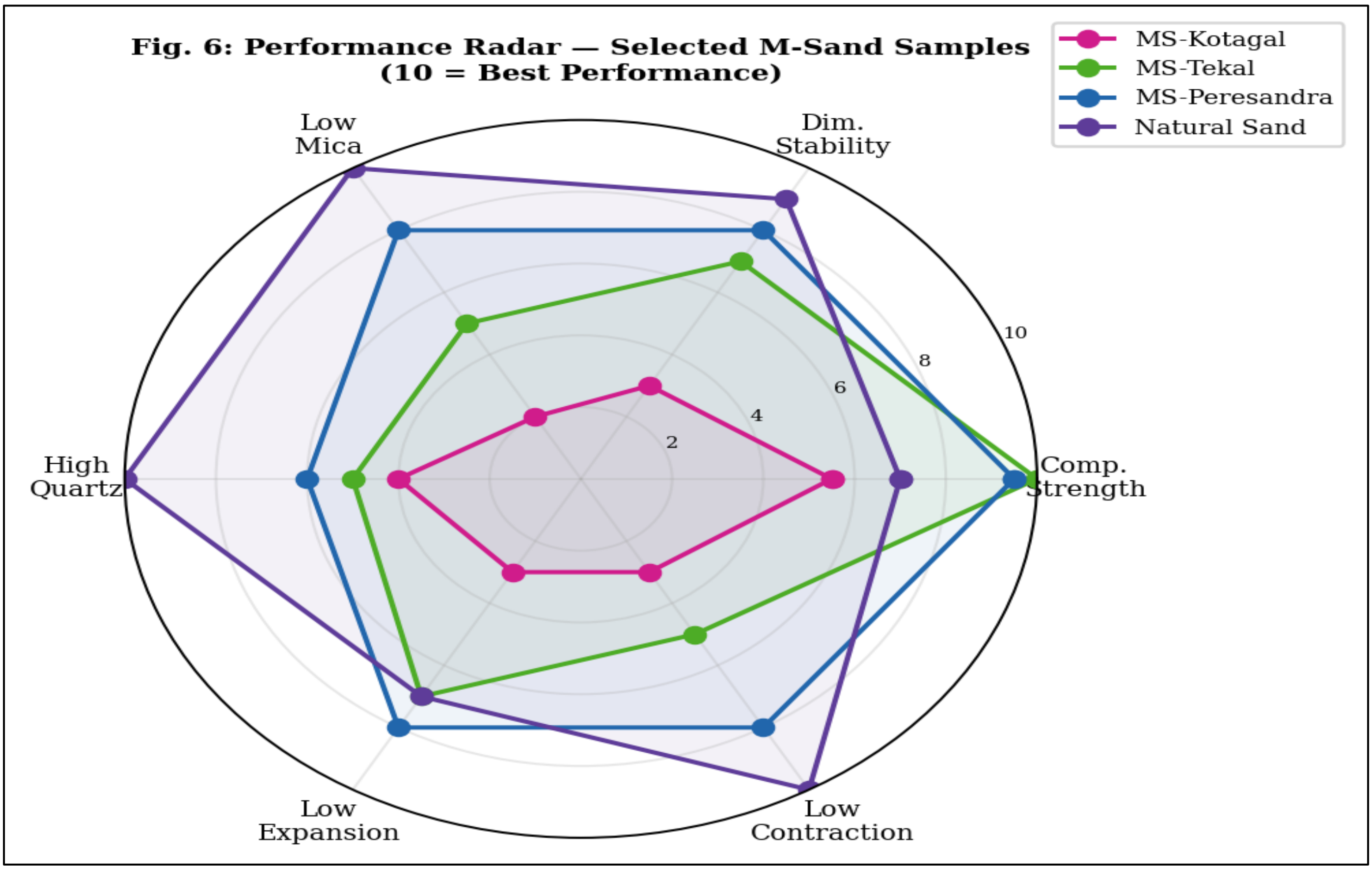

Fig 6 Performance Radar Chart — Comparative Evaluation of Selected M-Sand Samples (10 = Best)

The radar chart (Fig. 6) consolidates six performance indicators—compressive strength, dimensional stability, mica level, quartz content, expansion resistance, and contraction resistance—normalized on a 0–10 scale. MS-Peresandra and MS-Tekal offer the most balanced performance for construction mortar applications, while MS-Kotagal is clearly compromised by its elevated mica content. Natural sand remains superior in dimensional stability but is unavailable as a sustainable resource.

- *Role of Individual Minerals*

Feldspar content (34–43%) influenced the rate and timing of dimensional changes rather than their magnitude. Samples with higher feldspar (MS-Peresandra: 43.33%; MS-Tekal: 40.83%) showed more gradual expansion-contraction profiles. Quartz correlated positively with expansion magnitude but negatively with contraction—natural sand (54.17% quartz) showed highest expansion yet lowest contraction, consistent with quartz rigidity inhibiting shrinkage. The absence of olivine across all samples confirms non-mafic, granite-type source rock character, acceptable for construction purposes.

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V. CONCLUSIONS

This study provides experimental evidence linking the mineralogical composition of Karnataka M-sand to cement mortar performance.

➢ *Key Conclusions are:*

- Mica content is the dominant mineralogical factor governing volumetric instability and compressive strength reduction. A 7% increase in mica content reduces 28-day strength by 9–13% and significantly amplifies AMBT dimensional changes.
- MS-Kotagal (25% mica) exhibited maximum expansion (1.82 mm) and contraction (1.75 mm), while Natural Sand (9.17% mica) and MS-Peresandra (15% mica) showed best dimensional stability.
- MS-Tekal achieved the highest compressive strength (55.64 N/mm²) despite 20% mica content, attributed to higher feldspar (40.83%) and lower weathering alteration products in its parent granite.
- Width and depth changes (6–8%) consistently exceeded length changes in all mortar bars, indicating anisotropic swelling from mica flake orientation during casting.
- Quartz content promotes expansion but resists contraction; mica governs shrinkage; feldspar moderates the rate but not magnitude of dimensional change.
- For plastering mortar in Karnataka, M-sand with mica content below 20% (MS-Muddenahalli, MS-Tekal, MS-Peresandra) is recommended for adequate dimensional stability and compressive strength.
- The 1:2.25 mix amplified dimensional changes versus 1:1 mix, highlighting the importance of mix design optimisation when using high-mica M-sand.

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APPENDIX

EXPERIMENTAL PHOTOGRAPHS

➢ *Materials Preparation and Equipment*

Fig 7 Mortar Bar Casting Setup and Mould

➢ *Accelerated Mortar Bar Test (AMBT) — Hot Air Oven Setup*

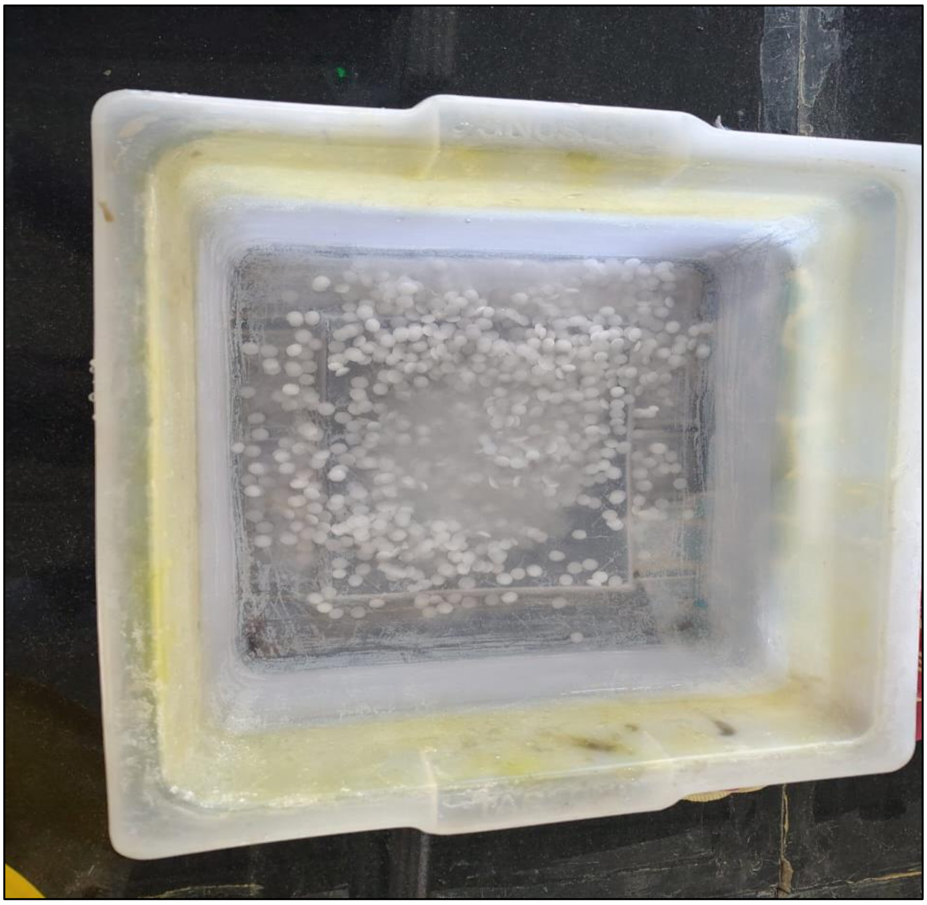

Fig 8 Mortar Bars Immersed in 1N NaOH at 80°C in Hot Air Oven

➢ *Mortar Cube Compression Testing*

Fig 9 Tested Mortar Cubes Showing Failure Pattern

➢ *Petrographic Microscopy — Thin Section Images*

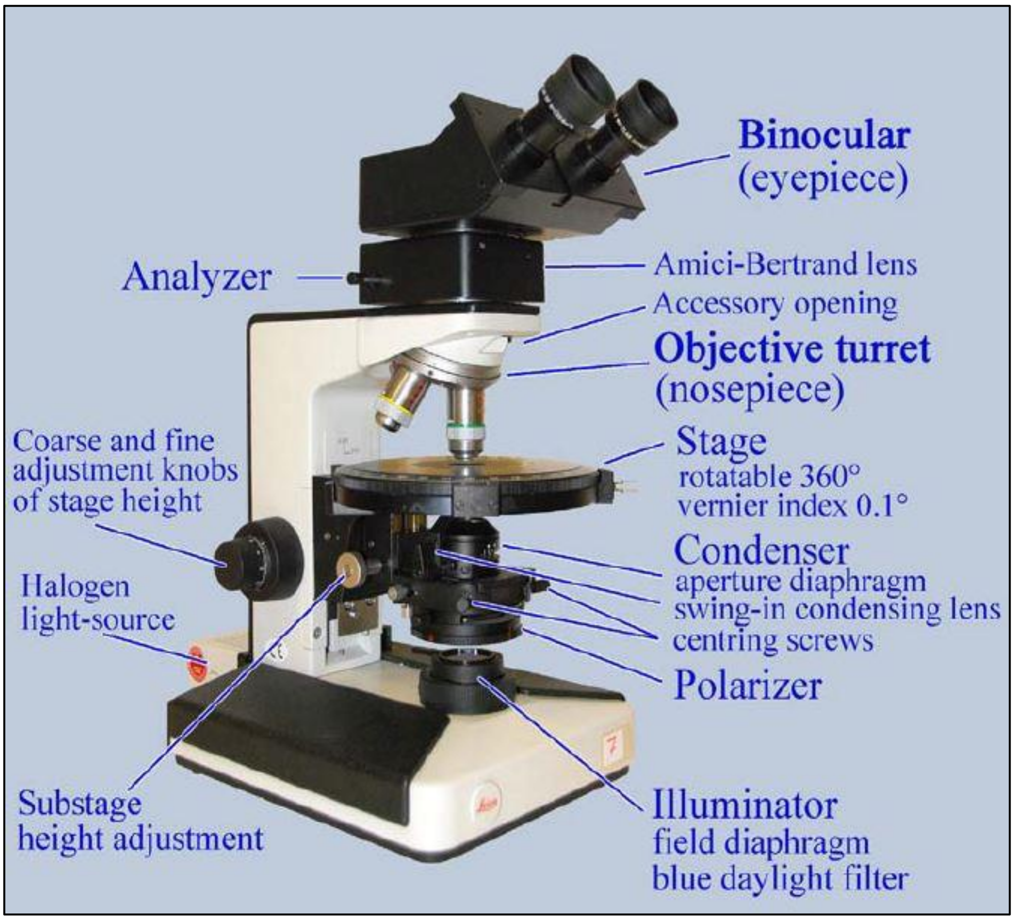

Fig 10 Olympus MX40 Polarizing Microscope (left)

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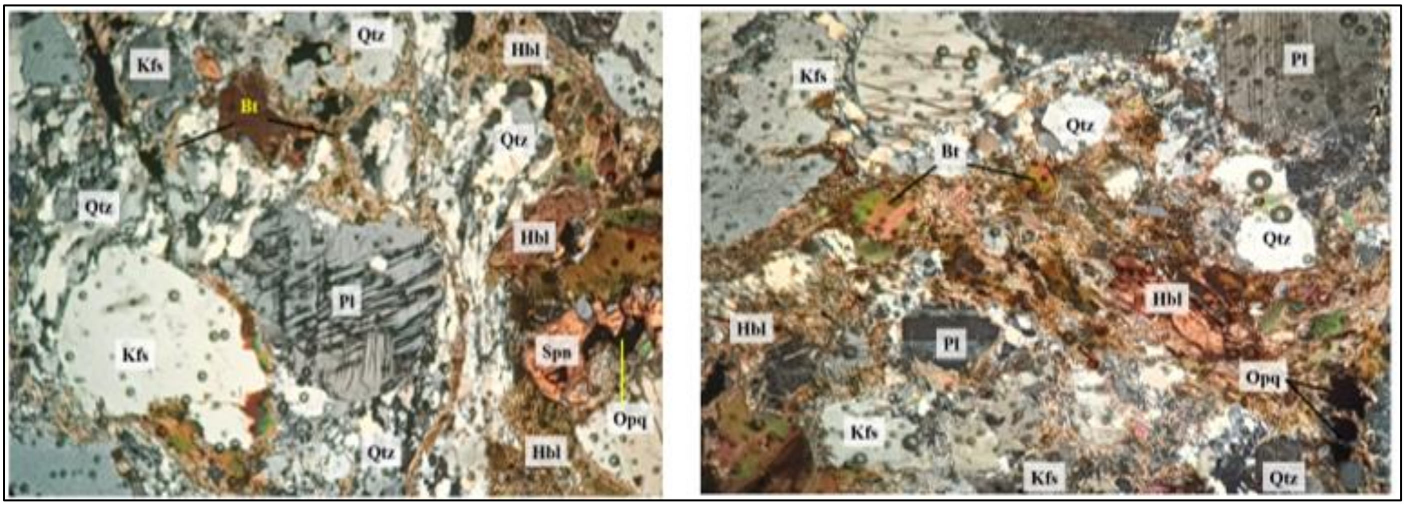

Fig 11 Thin Section Petrography — MS-Tekal (Hornblende-Biotite Granite) Porphyroclasts of mica and feldspar; albite-carlsbad twinning in plagioclase

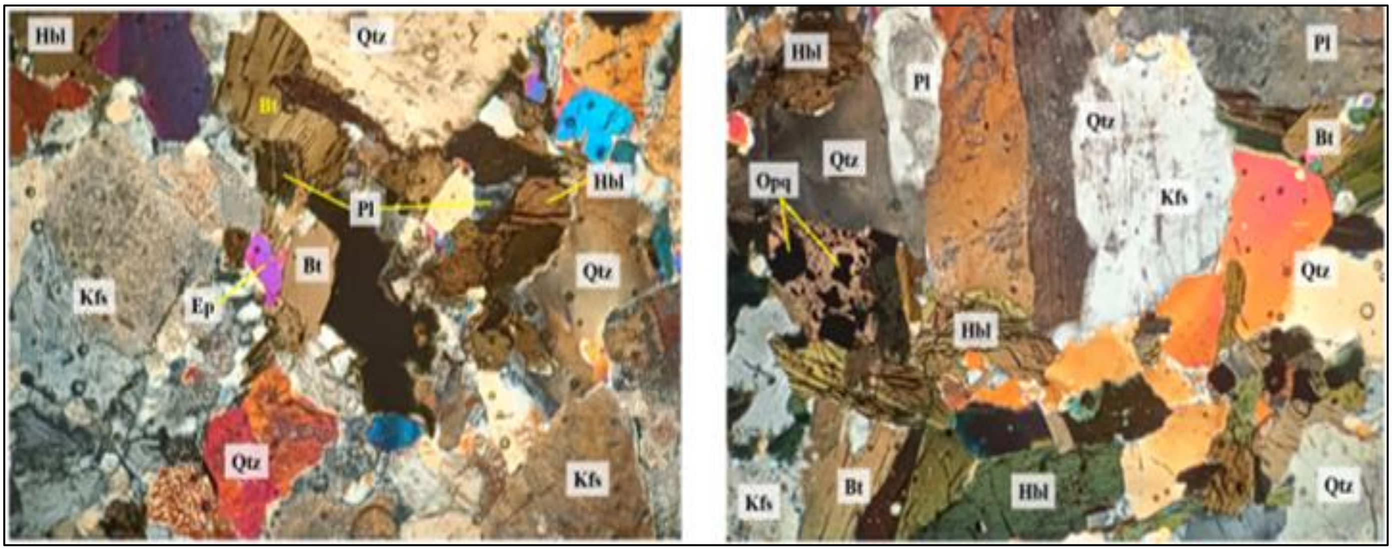

Fig 12 Thin Section Petrography — MS-Kotagal (Hornblende-Biotite Granite) Plagioclase overgrown by feldspar rims; biotite associated with iron oxide; intergrowth quartz

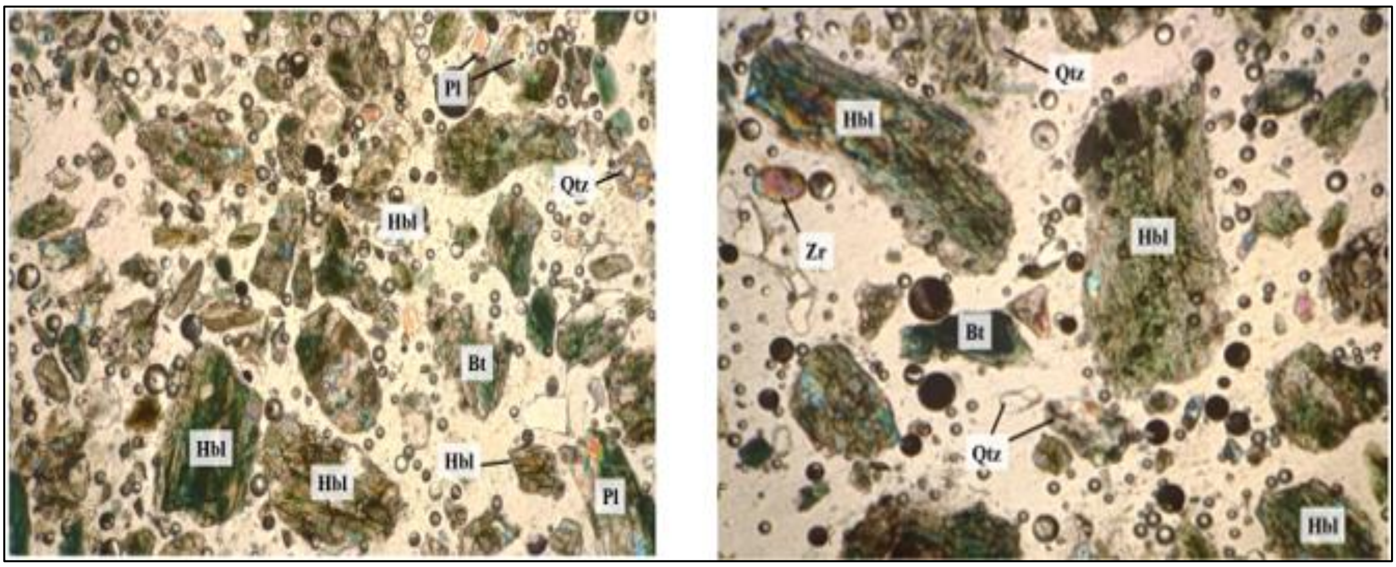

Fig 13 Thin Section Petrography — MS-Vishnupriya (Hornblende Granite) Major mineral constituents: quartz, plagioclase, potash feldspar, biotite, hornblende

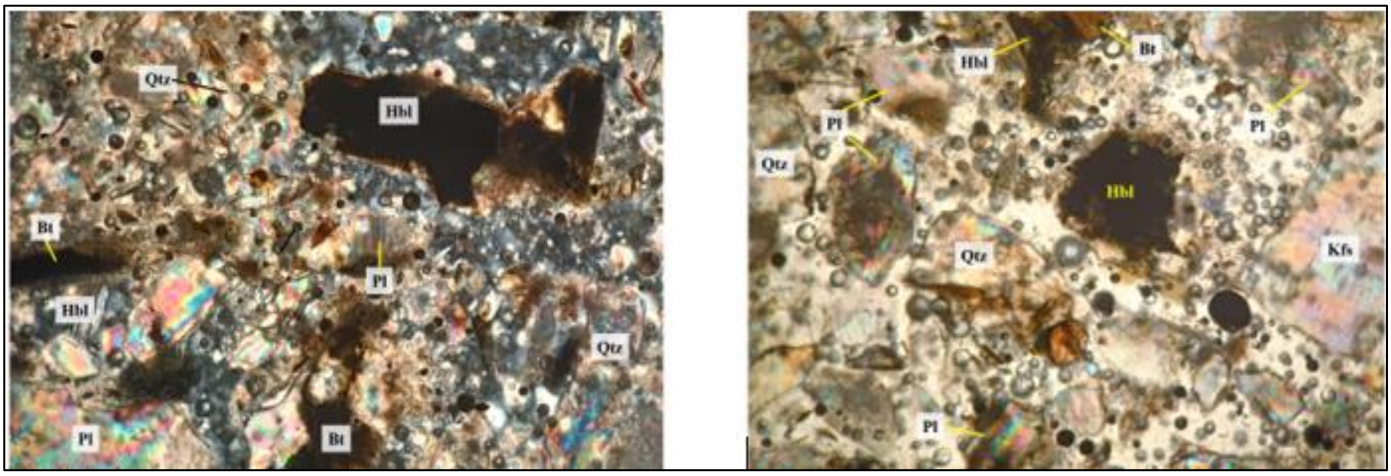

Fig 14 Thin Section Petrography — MS-Muddenahalli (Hornblende-Biotite Granite)

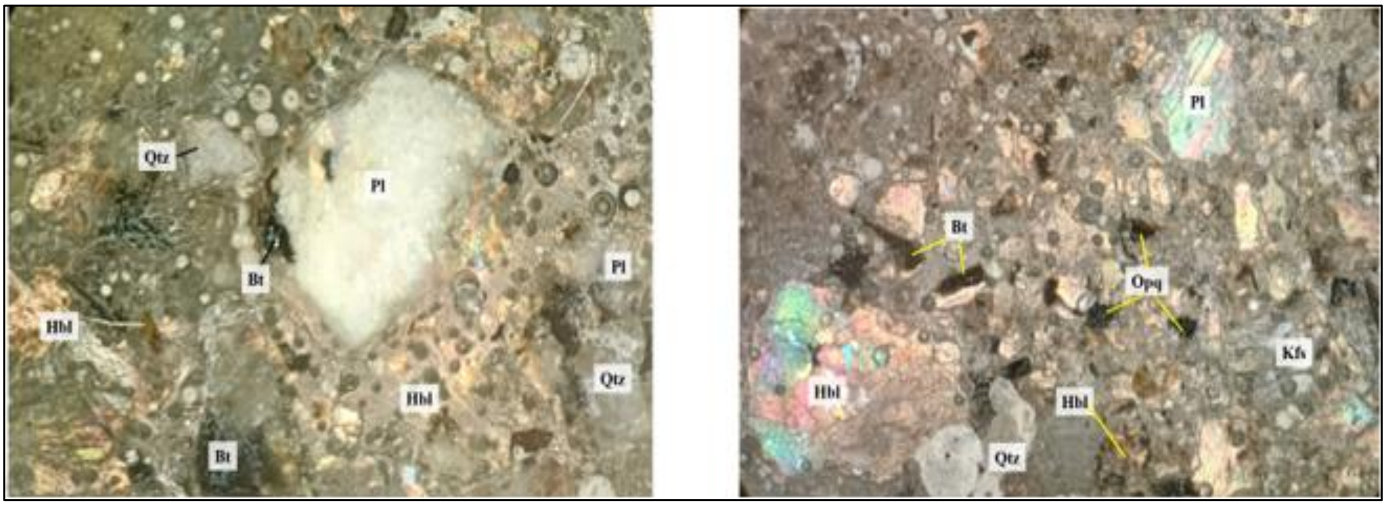

Fig 15 Thin Section Petrography — MS-Peresandra (Biotite Granite) Equigranular texture; quartz, plagioclase, potash feldspar, biotite, hornblende