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Subsurface and Environmental Triggers of Crack Recurrence in RCC Buildings: A Hybrid Field Analysis

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***Abstract:** This study investigates the environmental and geotechnical causes behind recurrent cracking in reinforced cement concrete (RCC) structures. Drawing on field data from 40 case studies across Tamil Nadu and Karnataka, the paper explores the correlation between soil type, drainage provision, foundation systems, and crack recurrence. Using a hybrid methodology that combines statistical analysis with engineer-led field insights, the study identifies clayey soils and lack of drainage as key contributors to high-severity, recurring cracks. Chi-square tests and Cramér's V validate the observed relationships. The findings advocate for integrating environmental variables into RCC diagnostic protocols, and propose a field-applicable Environmental Diagnostic Priority Matrix to guide structural monitoring and intervention strategies.*
***Keywords:** RCC Crack Recurrence, Soil Type, Drainage, Foundation Systems, Environmental Risk, Hybrid Field Analysis, Diagnostic Matrix*

I. INTRODUCTION

While structural flaws and material degradation have long been recognized as contributors to cracking in RCC structures, the role of subsurface and environmental conditions is often underrepresented in diagnostic models (Zornberg and Mitchell 1994; Golewski 2023; Akduman and Öztürk 2024). Poor soil bearing capacity, water retention due to insufficient drainage, and weak plinth protection amplify stress redistribution and induce recurring cracks (Wang et al. 2023; Seo et al. 2014). This study addresses the diagnostic gap by systematically linking these environmental variables to recurrence risk.

II. METHODOLOGY

Data were collected from 40 RCC buildings surveyed through structured observation checklists and expert interviews. Methodological integration followed principles from hybrid diagnostic frameworks (Wang et al. 2023; Zornberg and Mitchell 1994), combining statistical pattern recognition with qualitative validation.

Four tables inform the analysis:

1) Table 3: Soil & Foundation Context
2) Table 6: Environmental Triggers (Drainage, Plinth Protection)
3) Table 9: Soil Type × Recurrence Risk
4) Table 10: Drainage × Crack Severity

Variables were analyzed using chi-square tests and Cramér's V to assess the association between soil/drainage conditions and observed recurrence or severity patterns.

III. RESULTS

A. *Influence of Soil Type on Recurrence Risk*

Clayey soils accounted for 50% of high-recurrence cases, compared to only 14.8% in the low-risk group. Red soil showed better performance overall. The chi-square value (9.73, $p = 0.044$) and Cramér's V (0.36) confirm a moderate, significant association.

B. *Foundation Systems and Subsurface Behaviour*

Structures with isolated footings in mixed-soil conditions were more prone to differential settlement and recurring cracks. Load-bearing types in clay zones showed higher stress concentrations, reinforcing prior assumptions in field engineering logic.

C. Drainage and Crack Severity

Lack of drainage was strongly associated with medium and high-severity cracks: 88.9% of medium and 90.9% of high-severity cases occurred where no drainage was present. Chi-square = 13.26, p = 0.0013; Cramér's V = 0.58, indicating strong statistical association.

D. Environmental Clustering of Risk

Buildings without both plinth protection and proper drainage were overwhelmingly represented in the high-severity and high-recurrence categories. These two factors operate cumulatively, making them critical diagnostic indicators.

IV. DISCUSSION

The findings reinforce that environmental and geotechnical neglect can independently cause or worsen cracking. Engineers' reports validated the empirical trends and often referenced moisture-related instability and insufficient soil preparation. Studies by Wang et al. (2023), Akduman and Öztürk (2024), and Golewski (2023) support these field-level findings.

By incorporating these triggers into routine diagnostic processes, engineers can anticipate structural deterioration before visible symptoms escalate. The study advocates the use of an Environmental Diagnostic Priority Matrix that ranks sites by soil type, drainage condition, and foundation design to aid early warning and planning.

V. CONCLUSION

Crack recurrence in RCC buildings is significantly shaped by subsurface and environmental variables. Clayey soils, poor drainage, and inadequate plinth detailing represent latent threats that manifest over time. This hybrid field study supports integrating these variables into crack classification and response protocols for more accurate and context-aware diagnostics.

Appendix A: Tables

Table 3: Soil & Foundation Context

Characteristic/Category	Frequency / Mean	Percentage / Std. Dev.
Red Soil	24	60.0%
Clay / Clayey Soil	10	25.0%
Sandy Soil	6	15.0%
Isolated Footing	25	62.5%
Continuous Footing	12	30.0%
Base Slab / Other	3	7.5%
Load Bearing Structure	21	52.5%
Framed Structure	19	47.5%
SBC Mean	296.9 kN/m²	SD = 64.3

Source: Computed from Field Data

Table 6: Environmental Triggers

Characteristic	Frequency	Percentage
Nearby Construction	8	20.0%
No Nearby Construction	32	80.0%
Ground Movement Signs	10	25.0%

Characteristic	Frequency	Percentage
No Ground Movement	30	75.0%
Plinth Protection Yes	12	30.0%
Plinth Protection No	28	70.0%
Drainage Provided	14	35.0%
No Drainage	26	65.0%

Table 9: Soil Type × Recurrence Risk

Soil Type	Low (n=27)	Medium (n=5)	High (n=8)
Red	17 (63.0%)	4 (80.0%)	3 (37.5%)
Clay	4 (14.8%)	2 (40.0%)	4 (50.0%)
Sandy	6 (22.2%)	0 (0.0%)	1 (12.5%)

Source: Computed from Field Data

Table 10: Drainage Provided × Severity Level

Drainage Provided	Low (n=20)	Medium (n=9)	High (n=11)
Yes	12 (60.0%)	1 (11.1%)	1 (9.1%)
No	8 (40.0%)	8 (88.9%)	10 (90.9%)

Source: Computed from Field Data

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