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Crack Investigation and Residual Strength Check of Beams in an Existing Six-Story Reinforced Concrete Industrial Building in Bangladesh

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ABSTRACT

Old industrial buildings in Bangladesh often stay in full production use for many years after they are built, and cracks in their beams are a common concern. This paper looks at one such case: a six-story reinforced concrete (RC) factory building, where cracks were found in beams and slabs on four roof levels (2nd to 5th floor). The investigation had three simple steps. First, every crack was marked, photographed, and compared with the original drawings. Second, four basic non-destructive tests were used at the crack locations: ultrasonic pulse velocity (UPV) to check the crack depth and concrete quality, a carbonation test to see whether the crack had reached the steel bars, a half-cell test to check for corrosion, and a cover-meter survey to check the concrete cover. Third, for one critical beam on each floor, the load-carrying capacity was recalculated using the reduced beam depth caused by the crack, following the Bangladesh National Building Code (BNBC-2006). In total, 35 cracked beam and slab spots were surveyed across the four floors. Of these, 22 cracks went deeper than the main steel bar, 6 stopped within the concrete cover, and 7 were only surface plaster cracks. At the 14 spots where both crack depth and width were measured, depth ranged from 2.4 to 6.5 inches (mean 4.4 in., SD 1.2 in.) and width ranged from 0.03 to 0.20 mm (mean 0.09 mm, SD 0.05 mm); the two showed only a weak relationship (Pearson r = 0.18), so a deeper crack did not necessarily mean a wider one. Concrete quality from the UPV test was "good" or "excellent" everywhere it was tested, and the half-cell tests found no active corrosion. Concrete cover measured 35–60 mm (mean 44 mm), comfortably above the usual 25 mm minimum. The strength checks on the four critical beams showed that, even after subtracting the crack depth from the beam's effective depth, the steel already in place was still enough to carry the code-required bending moment in every case. The most likely cause of the cracking is poor compaction and curing during the original construction, not corrosion or overloading. A step-by-step repair plan is given — heavier repair (remove damaged concrete, clean the bar, patch and re-plaster) for cracks that reached the bar, and a lighter wire-mesh plaster repair for shallower cracks — together with a crack-width monitoring schedule and a temporary 2 kPa live-load limit until repairs are finished. The results give a simple, data-based approach that other engineers can reuse to check similar older factory buildings.

INTRODUCTION

Reinforced concrete (RC) buildings are the most common type of factory building in Bangladesh, especially in the ready-made garment and knitwear industry. Many of these buildings keep running in full production for decades, with little downtime for maintenance. This constant use, together with humid indoor conditions and construction that is sometimes rushed to meet delivery deadlines, can lead to problems such as poor compaction of concrete, honeycombing, and insufficient curing at the time of construction. Over the years, these hidden weaknesses often show up as visible cracks in beams and slabs.

A crack in a concrete beam is not automatically a safety problem. Small, hairline cracks caused by shrinkage are normal and usually harmless. The real question is whether a crack has gone deep enough to reach the steel reinforcement, because that can let in air and moisture, encourage corrosion, and reduce the effective depth of the beam — the part of the beam that actually resists bending. Telling a harmless plaster crack apart from a structurally important one is not something that can be done by eye alone; it needs a mix of close visual inspection, simple field tests, and a basic engineering check of the beam's remaining strength.

A number of non-destructive tests (NDTs) are commonly used for this kind of check: ultrasonic pulse velocity (UPV), rebound hammer, half-cell potential, cover-meter survey, and carbonation depth testing. These tests have been used successfully in many recent studies of aging RC buildings in South Asia and elsewhere to sort structures into "repairable" and "needs major work" categories, based on combined visual and NDT evidence (Basack *et al.*, 2026). Emerging digital tools, such as augmented-reality-assisted inspection, are also being explored as a way to speed up field data collection and reduce human error in condition surveys of civil infrastructure (Afolabi *et al.*, 2026), although the present study relies on conventional, field-proven NDT methods. Beyond inspection itself,

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Building Information Modeling (BIM) is increasingly being proposed as a way to organize and update as-built structural records for exactly this kind of condition survey and repair documentation, though adoption in Bangladesh and other developing construction markets remains limited by cost, skills, and institutional barriers (Adeeko & Akinola, 2025; Jany *et al.*, 2026).

This paper reports a crack investigation of an existing six-story RC factory building in Bangladesh, where cracks were found in beams and slabs on four roof levels. This kind of applied, field-data-driven case study sits alongside a growing body of regional civil-engineering research addressing practical infrastructure performance questions, from urban drainage geometry (Saad, 2025b) to sustainable construction materials, that together aim to close the gap between international standards and the specific construction and climate conditions found across South Asia and neighboring regions. The paper has three goals: (i) to record and classify every crack found, using visual survey together with the four NDTs listed above; (ii) to check, using the crack-reduced beam depth and the BNBC-2006 design rules, whether the cracking has actually reduced the beam's ability to carry load; and (iii) to set out a practical, crack-type-specific repair plan and a monitoring schedule that allows the factory to keep operating, under a temporary reduced live load, while repairs are completed.

MATERIALS AND METHODS

The Building

The building studied is an existing, partially built six-story RC industrial structure. The survey covered the roof-level beams and slabs of the 2nd, 3rd, 4th, and 5th floors. Two beam sizes were found repeatedly across the surveyed grid lines: a 12 in. × 24 in. beam (referred to here as Type FB-1) and a 10 in. × 24 in. beam (Type FB-3). Span lengths were between about 22.6 and 23.3 ft, and the beams supported a 6-in.-thick RC slab.

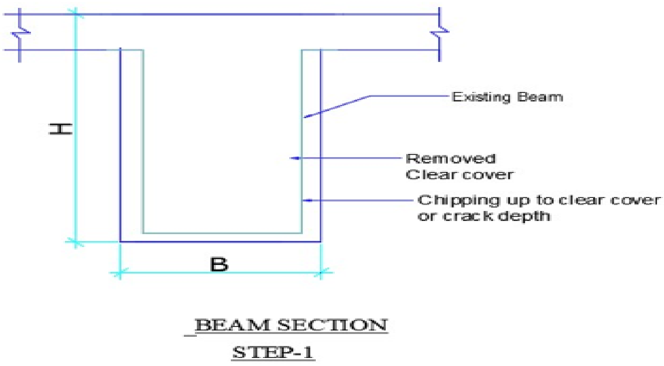

Figure 1: Generic beam cross-section (width B × depth H) used to define the crack-reduced effective depth in the strength check.

Visual Crack Survey

Every beam and slab on the four roof levels was visually inspected. Beam positions and sizes were checked against the original structural drawings. Each crack that was found was marked, given a unique ID (for example 2A, 3B, 4G, 5C — the number is the floor, the letter is the crack), and exposed by removing the surface plaster so that the bare concrete, and the reinforcing bar underneath it where relevant, could be seen directly. Each crack was then placed into one of three simple categories: (i) crack goes past the main reinforcement bar, (ii) crack stays within the concrete cover only, or (iii) crack is only in the plaster finish, with no structural concrete involved.

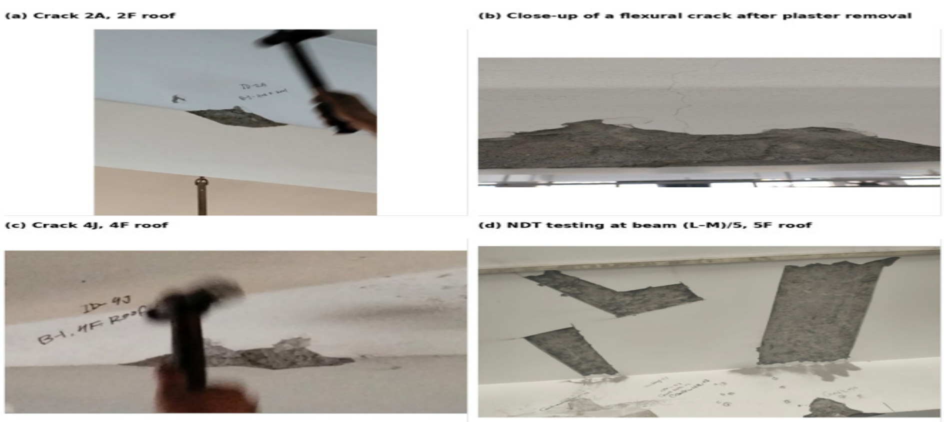

Figure 2: Representative field photographs from the crack survey: (a) crack 2A on the 2nd floor roof; (b) close-up of a flexural crack after plaster removal; (c) crack 4J on the 4th floor roof; (d) NDT testing (UPV, carbonation, crack width) at beam (L–M)/5 on the 5th floor roof.

Field Tests

At selected crack locations on all four floors, four standard field tests were carried out: Ultrasonic pulse velocity (UPV) test, following ASTM C597 (ASTM International, 2023), used to estimate the crack depth and to rate the concrete quality around the crack as poor, doubtful, good, or excellent. Carbonation depth test, using the phenolphthalein color-change method (Woyciechowski *et al.*, 2022) (a simple spray test: the concrete changes color where it is still "healthy," and stays colorless where carbonation has damaged it) on freshly exposed concrete, to check whether the carbonation front had reached the level of the steel bar. Half-cell potential test, following ASTM C876 (ASTM International, 2022) and standard half-cell potential mapping practice (Elsener *et al.*, 2003), used at selected points to estimate how likely the steel was to be actively corroding. Cover-meter survey, used with a hand-held electromagnetic cover meter to check the actual concrete cover over the main bar at selected beam faces.

Beam Strength Check

For each of the four floors, the beam with the deepest UPV-measured crack was chosen as the critical case for a strength check. The beam's effective depth (the distance from the top of the beam to the center of the tension steel, written as d) was reduced by the measured crack depth, giving a conservative, crack-reduced value of d. Gravity loads on the tributary area of each beam (the portion of floor whose weight that beam actually carries) — self-weight, floor finish, partition wall, and live load — were combined using the standard load factors of 1.4 for dead load and 1.7 for live load. Positive and negative bending moments were estimated with the approximate coefficients for continuous beams given in BNBC-2006 (Housing and Building Research Institute, 2006, Table 6.6.2), using $wL^2/16$ and $wL^2/11$ respectively for the spans checked. The steel area required to resist this moment was then calculated with $f'c$ = 3.042 ksi and fy = 60 ksi, using the standard flexural design formula, and compared with the steel already present in the beam.

RESULTS AND DISCUSSION

How Many Cracks, and How Serious

A total of 35 cracked beam and slab locations were found and surveyed across the four roof levels (Table 1). The 2nd floor had 6 cracked beams, the 3rd floor had 4, the 4th floor had 17, and the 5th floor had 6 cracked beams plus 2 plaster-only cracks on the slab. Out of the 35 locations, 22 (about two out of every three) had cracks that went past the main reinforcement bar, 6 stayed within the concrete cover, and the remaining 7 were plaster-only. The 4th floor had by far the most bar-deep cracks (11 out of 22), matching its higher overall crack count.

Table 1: Number of cracks found on each floor, by type

Floor level	Total cracked spots checked	Crack past main bar	Crack within cover only	Plaster-only crack	% of building total
2nd floor roof	6	3	2	1	17.1%
3rd floor roof	4	2	1	1	11.4%
4th floor roof	17	11	3	3	48.6%
5th floor roof (beams)	6	6	–	–	17.1%
5th floor roof (slab)	2	–	–	2	5.7%
Total	35	22 (62.9%)	6 (17.1%)	7 (20.0%)	100%

No sign of rusted or corroded reinforcement was seen at any of the exposed cracks, which matches the half-cell test results reported below.

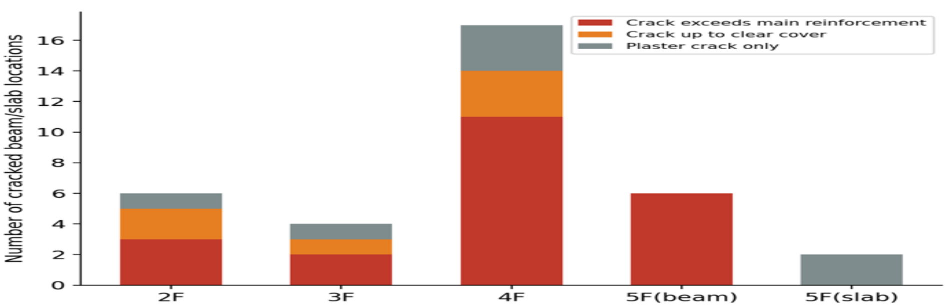

Figure 3: Number of cracks on each floor, split by how serious they are.

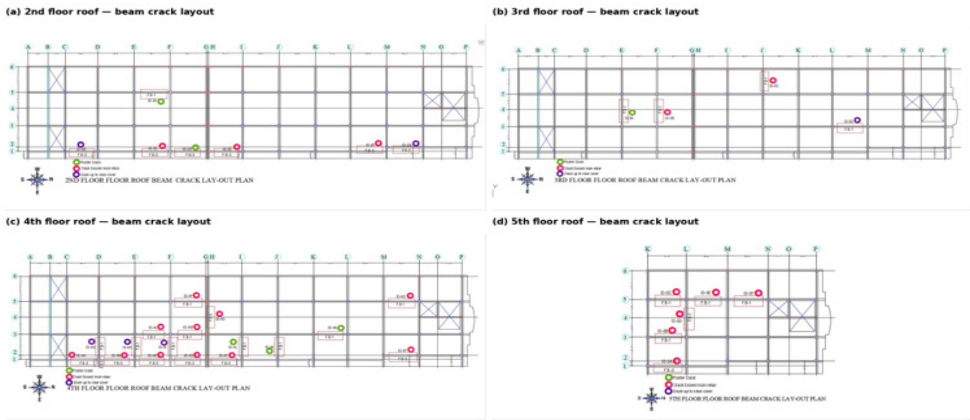

Figure 4: Beam crack layout plans for the four surveyed roof levels, showing grid lines and individual crack IDs colour-coded by severity: (a) 2nd floor, (b) 3rd floor, (c) 4th floor, (d) 5th floor.

Field Test Results

Table 2 lists the full set of 14 crack locations where both crack depth and crack width were measured. Depth ranged from 2.4 in. (crack 5B) to 6.5 in. (crack 4D), and width ranged from 0.03 mm to 0.20 mm. Concrete quality from the UPV test came out "good" at almost every point and "excellent" at one (crack 5E), showing that the concrete itself, away from the crack, was still sound. Carbonation had reached the level of the steel bar at six of the fourteen tested spots (3B, 3C, 4A, 4C, 4M, 4Q) but not at the other eight. Half-cell readings taken at three spots (2C, 3D, 5E) all came back at 0% corrosion probability, and cover-meter readings taken at 12 points ranged from 35 to 60 mm, all above the usual 25 mm minimum design cover.

Table 2: Full dataset: crack depth, crack width, concrete quality, and carbonation status at all 14 tested locations

Crack ID	Floor	Crack depth (in.)	Crack width (mm)	Concrete quality (UPV)	Carbonation reached bar?
2C	2F roof	4.0	0.04	Good	No
2E	2F roof	3.0	0.03	Good	No
2F	2F roof	5.3	0.20	Good	No
3B	3F roof	5.4	0.04	Good	Yes
3C	3F roof	3.6	0.05	Good	Yes
4A	4F roof	4.9	0.08	Good	Yes
4C	4F roof	5.8	0.07	Good	Yes
4D	4F roof	6.5	0.10	Not tested	No
4F	4F roof	4.4	0.07	Good	No
4M	4F roof	5.7	0.07	Good	Yes
4Q	4F roof	2.4	0.08	Good	Yes
5B	5F roof	2.9	0.10	Good	No
5D	5F roof	4.2	0.14	Good	No
5E	5F roof	3.9	0.12	Excellent	No

Statistical Summary of the Test Data

To give a clearer, numbers-based picture of the survey, basic descriptive statistics were calculated for the three measured quantities: crack depth, crack width, and concrete cover (Table 3). Crack depth averaged 4.4 in. with a standard deviation of 1.2 in.; crack width averaged 0.09 mm with a standard deviation of 0.05 mm; and cover meter readings averaged 44 mm with a standard deviation of 7.6 mm, comfortably above the 25 mm minimum typically used in design. A Pearson correlation (a standard statistical score from 0 to 1 showing how closely two measurements move together) between crack depth and crack width across the 14 paired readings gave r = 0.18, which is a weak relationship — in other words, a deeper crack was not reliably a wider one, and the two measurements should be read as independent indicators rather than substitutes for one another (Fig. 5).

Table 3: Descriptive statistics of the field measurements

Parameter	n	Mean	SD	Minimum	Maximum	Median
Crack depth (in.)	14	4.43	1.22	2.4	6.5	4.30
Crack width (mm)	14	0.09	0.05	0.03	0.20	0.08
Concrete cover (mm)	12	44.2	7.6	35	60	40.0

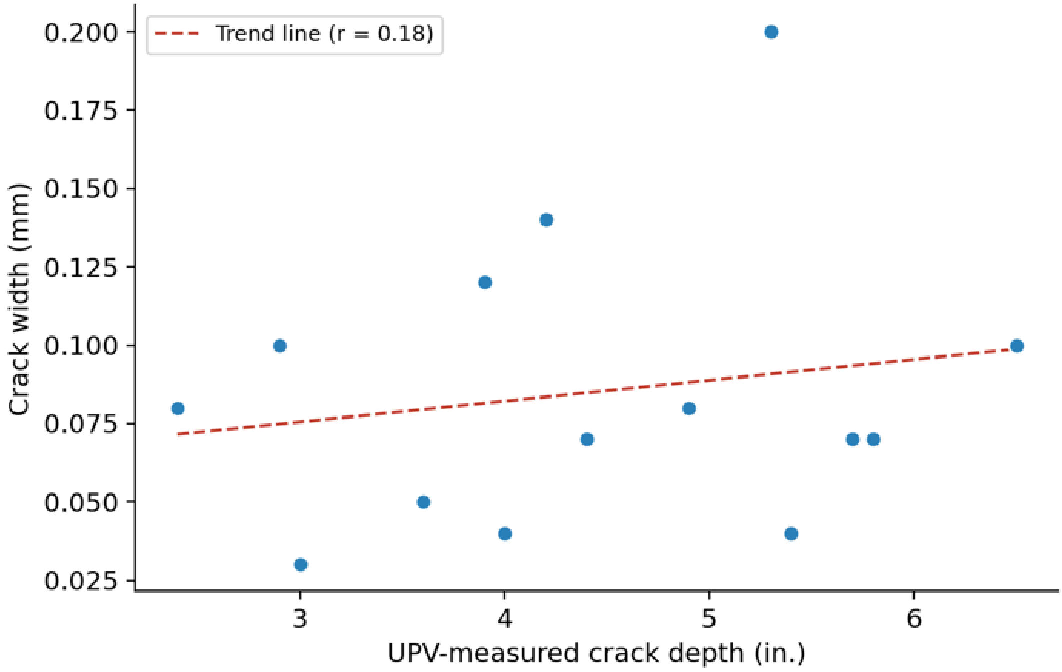

Figure 5: Crack depth plotted against crack width for the 14 tested locations, showing only a weak relationship (r = 0.18).

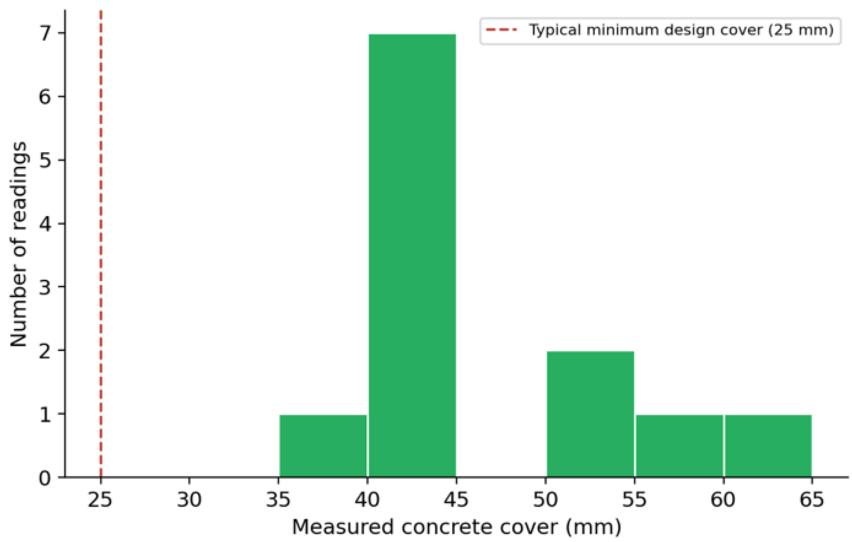

Figure 6: How the 12 concrete-cover readings were spread out, compared with the usual 25 mm minimum design cover.

Splitting the same crack-depth data by floor gives a rougher, but still useful, picture of where the deepest cracking is concentrated (Table 5, Fig. 7). The 4th floor had both the most tested cracks and the deepest cracking on average (mean 4.95 in.), while the 5th floor had the shallowest average depth (3.67 in.) and the smallest spread between readings (SD 0.68 in.). Because each floor only has two to six tested points, these per-floor numbers should be read as a general trend, not as a precise comparison.

Table 5: Crack depth by floor (tested locations only

Floor	n	Mean depth (in.)	SD (in.)	Minimum (in.)	Maximum (in.)
2F roof	3	4.10	1.15	3.0	5.3
3F roof	2	4.50	1.27	3.6	5.4
4F roof	6	4.95	1.45	2.4	6.5
5F roof	3	3.67	0.68	2.9	4.2

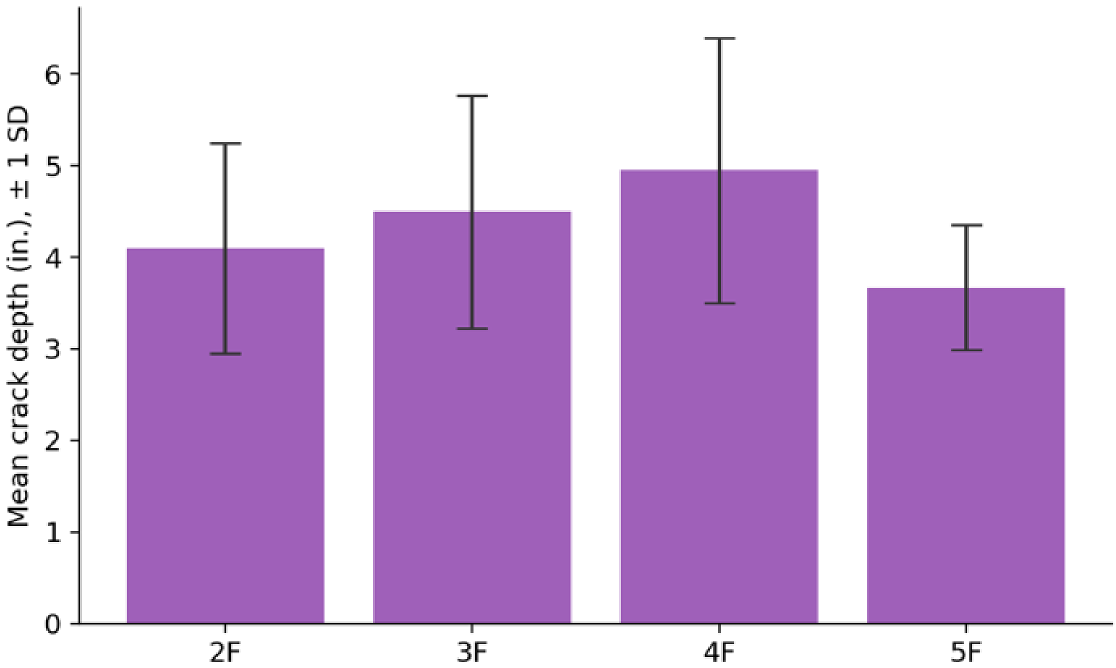

Figure 7: Average crack depth on each floor, with error bars showing one standard deviation.

Beam Strength Check Results

Table 4 shows the strength check for the single most critical beam on each floor, using the crack-reduced beam depth. In all four cases, the steel already present in the beam was more than the code requires, for both the positive-moment (mid-span, sagging) and negative-moment (over-support, hogging) regions. To make this easier to compare across floors, the last column gives the governing capacity margin — simply (steel provided − steel needed) ÷ steel needed, taking whichever of the two moment checks is tighter for that beam, expressed as a percentage. This margin ranged from 0% on the 3rd floor (where provided and required negative-moment steel were almost exactly equal) to 27% on the 5th floor. In other words, even the tightest case still met the code requirement exactly, and none of the four critical beams showed a shortfall in bending strength once the crack depth was accounted for.

Table 4: Beam strength check using the crack-reduced effective depth

Floor	Beam / grid	Crack-reduced d (in.)	Steel needed / provided, mid-span (in²)	Steel needed / provided, over support (in²)	Governing margin	Result
2F roof	FB-3, (E–F)/1	18.7	1.87 / 2.40	2.47 / 2.88	17%	Sufficient
3F roof	FB-1, (3–5)/F	18.6	2.26 / 3.10	3.31 / 3.31	0%	Sufficient

4F roof	FB-3, (E–F)/1	18.2	1.54 / 2.40	2.32 / 2.88	24%	Sufficient
5F roof	FB-1, (L–M)/5	20.1	1.77 / 3.10	2.61 / 3.31	27%	Sufficient

Discussion

What Most Likely Caused the Cracking

Most of the cracks ran vertically down the side of the beams, in the pattern typically associated with flexural cracking rather than with shrinkage, thermal movement, or other non-structural causes (American Concrete Institute, 2001). At the same time, no corrosion was seen anywhere, and the concrete around the cracks tested as "good" to "excellent" in nearly every case. Taken together, this points to a construction-quality problem — most likely poor compaction (leading to honeycombing) and insufficient curing when the concrete was originally placed — rather than corrosion, overloading, or a general material defect across the building.

What This Means for the Building's Safety

The strength checks in Table 4 show that, for the four beams checked, the crack depth had not reduced the beam's bending strength below what BNBC-2006 requires. This fits with the fact that beams of this type are usually designed with more steel than the bare minimum needed, giving some built-in safety margin. Based on this, a repair-and-monitor approach is reasonable, rather than more disruptive options such as full member replacement. That said, this check only covers bending strength at one section of each beam; it does not cover shear strength, the long-term effect of carbonation at the six spots where it has already reached the bar, or serviceability issues like deflection, so ongoing monitoring after repair is still important. Crack width itself is a useful early-warning indicator of durability performance in RC members, since even small increases in width can accelerate future ingress of moisture and carbon dioxide (Mohibullah & Sheam, 2026), which is why the monitoring plan in Section 4.4 focuses specifically on tracking width over time rather than treating the beam as a one-time pass/fail check. The same underlying durability logic — that strength and long-term serviceability need to be assessed together, not strength alone — has also been demonstrated experimentally in recent evaluations of concrete durability under sustained loading and exposure (Ridoy *et al.*, 2026).

Repair Plan

A different repair method is recommended for each crack type, following the general assessment-and-repair framework of ACI 562-19 (American Concrete Institute, 2019). For cracks that go past the main bar: remove the plaster and any loose or cracked concrete, clean any exposed rusted bar with a wire brush, apply an anti-corrosion coating if needed, add shear connectors across the repaired section, apply an epoxy bonding agent before recasting, patch with micro-concrete, cure for at least 14 days after removing the formwork, and finish with 12 mm plaster and paint. For cracks that stay within the cover only: a lighter repair using wire mesh (1 mm thick, 25–38 mm spacing) bonded with epoxy primer, then plastered and painted, is enough. Where carbonation has reached the bar, the damaged cover concrete should be cleared back at least 1 in. past the bar and an anti-carbonation coating applied before patching. Bonding-agent selection matters for how well the new and old concrete act together; comparative work on alternative binding and bonding systems for concrete repair supports the choice of a dedicated epoxy bonding agent over a plain cement slurry at the repair interface used here (Saad, 2025a). For future repair batches, partial replacement of cement with pozzolanic supplementary materials is also worth considering, since such substitutions have been shown to improve compressive strength and chloride resistance in comparable concrete mixes without major cost penalties (Aanu *et al.*, 2025). Until these repairs are finished, a temporary live-load limit of 2 kPa is recommended on the affected floors so that production can continue on a restricted basis.

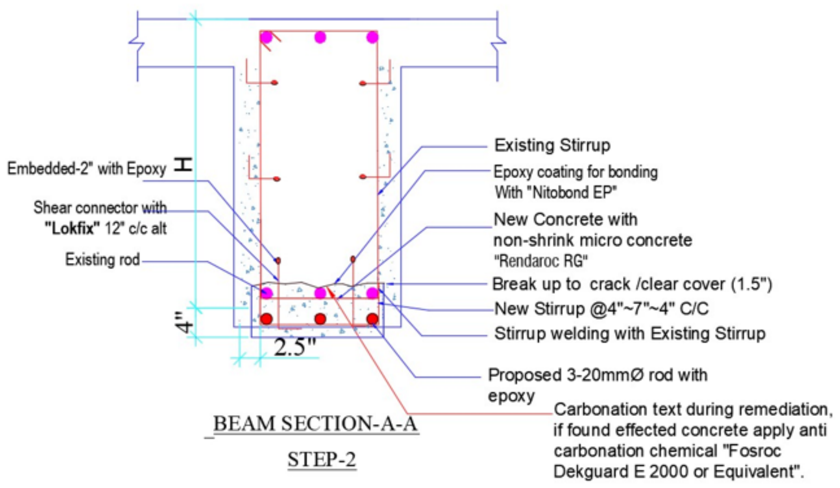

Figure8: Beam Section A–A repair detail for cracks exceeding the main reinforcement: existing stirrups, epoxy-coated bonding interface, new non-shrink micro-concrete, and welded supplementary stirrups.

Monitoring After Repair

A simple monitoring plan is recommended to confirm that each repair stays stable over time. Every repaired crack should be marked and numbered, with a baseline width reading taken right after the repair using a crack-width microscope, digital caliper, or feeler gauge (accurate to about 0.02–0.05 mm). Suggested checking frequency: weekly for the first month, every two weeks from month 1 to 3, monthly from month 3 to 6, and every three months after that, plus an extra check after any unusually heavy loading. Under BNBC-2020 (Housing and Building Research Institute, 2020), the allowable crack width for typical exposure is about 0.3–0.4 mm. In practice: no change in width means the repair is stable; growth of up to 0.05 mm means keep watching; and growth of more than 0.1 mm should trigger a fresh, detailed structural check.

CONCLUSION

Based on the visual survey, the field tests, and the beam strength checks carried out on this six-story RC factory building in Bangladesh, the main findings are:

- Thirty-five cracked beam and slab spots were found on the 2nd to 5th floor roofs; 22 cracks went past the main bar, 6 stayed within the cover, and 7 were plaster-only.
- Where measured (14 spots), crack depth ranged from 2.4 to 6.5 in. (mean 4.4 in.) and crack width from 0.03 to 0.20 mm (mean 0.09 mm); the two were only weakly related ($r = 0.18$).
- No active corrosion was found, and concrete quality tested “good” to “excellent” everywhere; concrete cover averaged 44 mm, above the usual 25 mm minimum. Carbonation had reached the bar at 6 of the 14 tested spots.
- Beam strength checks on the worst-case beam on each floor, using the crack-reduced depth, showed the existing steel was still enough to meet BNBC-2006 requirements in every case.
- The cracking is most likely due to poor compaction and curing during original construction, not corrosion or overloading.
- A crack-type-specific repair plan, a follow-up monitoring schedule, and a temporary 2 kPa live-load limit are recommended to restore the building to full serviceability while allowing continued factory use.

Recommendations

- Repair cracked beams following the crack-type-specific method and drawings developed for this investigation.
- Keep the live load on the affected floors at or below 2 kPa until repairs are complete.
- After repairs, keep the live load at 2 kPa unless a follow-up structural check justifies a higher value.
- Carry out the crack-monitoring plan on schedule, and inform the structural consultant immediately if a repaired crack reappears or widens past the stated limit.
- Take a small number of concrete cores and test their compressive strength (per ACI 214.4R-10; American Concrete Institute, 2010) to confirm the UPV-based quality ratings before the repair work is finally signed off.

Author Contributions

M.R.J.: Conceptualization, methodology, formal analysis, investigation, writing – original draft, writing – review and editing, project administration. S.I.: Data curation, investigation, validation, writing – review and editing. M.S.S.: Formal analysis, visualization, writing – review and editing. R.K.: Resources, supervision, writing – review and editing. All authors have read and agreed to the published version of the manuscript.

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Declaration of Generative AI and AI-Assisted Technologies

During preparation of this manuscript, the authors used a generative AI-based language model to assist with drafting, structuring, and language editing of the text, based on the authors’ own field investigation data, test results, and engineering calculations.

Conflict of Interest

The authors declare no conflict of interest.

Data Availability Statement

The field survey, test, and structural verification data supporting this study are available from the corresponding author on reasonable request.

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