

Rehabilitation and Retrofitting of Old RCC and Steel Buildings: An Evidence-Based Assessment Framework with Two Case Studies

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Abstract - Many reinforced concrete (RCC) buildings and steel industrial structures in India have reached an age at which deterioration, changed use and revised design codes make their continued safe service a matter for engineering evaluation. This paper presents an evidence-based framework for the assessment, rehabilitation and retrofitting of such structures and applies it to two case studies: a boys' hostel building at a polytechnic in Chandil, Jharkhand, and a steel loading gantry at a petroleum depot in Tata Nagar. The framework follows a staged workflow of records review, condition survey, testing, analysis, retrofit design and re-analysis, and it classifies every project-specific statement by evidence level so that verified, reported, assumed and recommended information are never mixed. For the RCC hostel, review of the available drawings, photographs and model-input report identified a configuration mismatch between the existing building and the design model, and imposed loads below the values given in the Indian loading code for hostels. Illustrative calculations showed that column and footing adequacy depend strongly on in-situ concrete strength and soil pressure. For the steel gantry, an illustrative purlin example showed that an assumed 35 percent section loss consumed most of the bending margin and that plate strengthening restored it. The paper does not claim that either structure is adequate. Its contribution is a transparent method for documenting retrofit case studies when evidence is incomplete, together with a list of the records that a defensible retrofit file must contain.

Keywords - existing RCC building; structural assessment; rehabilitation; retrofitting; RC jacking; steel corrosion; steel gantry; non-destructive testing

I. INTRODUCTION

A large share of the buildings and industrial structures now in service in India were designed to codes that have since been revised, were built with variable site quality, and have been exposed to decades of moisture, atmospheric pollutants and deferred maintenance. Reinforced cement concrete (RCC) frames and structural-steel canopies, sheds and gantries are the two systems most often met in institutional and industrial settings. When such structures reach middle age, owners face a practical question: can the structure continue to serve safely with routine repair, does it need strengthening, or should it be replaced?

Answering that question requires evidence. Visible distress is only a symptom, and the same stain, crack or flaking coating can have several unrelated causes. A sound decision therefore combines a records review, a systematic condition survey, material investigation, structural analysis that reflects the actual condition of the members, and an intervention design that is verified after the strengthening has been represented in the

analysis. ACI 562 [1], fib Bulletin 24 [2] and IS 15988 [3] all frame the problem in this way: understand the existing condition first, then define performance objectives, then design and verify the intervention. For reinforced concrete, the cause of deterioration must also be diagnosed before a repair method is chosen [4].

In this paper, *repair* means localised work that restores damaged material; *rehabilitation* means repair together with measures that restore durability, including removal of the moisture or corrosion source; *strengthening* means work that increases load-carrying capacity or stiffness; and *retrofitting* means the overall upgrade of a structure to meet a stated performance objective. Assessment is the evaluation of condition and residual capacity from records, survey, testing and analysis.

Reports on rehabilitation projects frequently describe the work carried out but not the evidence that justified it or the verification that followed. Case studies of existing structures are particularly prone to gaps: lost drawings, no raw test data, models that mix existing and proposed configurations, and conclusions that cannot be traced to calculations. The problem addressed here is how to document and critically evaluate retrofit case studies when the available evidence is incomplete, without discarding them and without filling the gaps with unsupported numbers.

The paper (i) sets out a staged assessment workflow, (ii) introduces evidence labels that separate verified, reported, assumed and recommended information, (iii) audits the evidence available for an RCC hostel building and a steel loading gantry, (iv) demonstrates the retrofit design logic through clearly labelled illustrative calculations, and (v) identifies the records that a defensible retrofit file must contain.

II. LITERATURE REVIEW AND STANDARDS

A. Assessment of Existing Structures

A recurring principle is that an existing structure should be evaluated against what it actually is, not what its drawings say it should be. ACI 562-19 sets minimum requirements for the assessment, repair and rehabilitation of existing structural concrete, compares demand and capacity against defined limits, and requires repair or strengthening where the existing structure does not meet them [1]. The fib Bulletin 24 prepared by Task Group 7.1 sets out a staged approach that moves from data collection to evaluation to intervention [2], and IS 15988:2013 gives the corresponding Indian guidelines for seismic evaluation and strengthening of existing RC buildings

[3]. These documents share a caution that is central here: an assessment is only as good as its inputs, and uncertainty in material strength and detailing should be carried into the conclusion rather than hidden by a single deterministic result.

B. Deterioration and Strengthening of RCC

Reinforcement is normally protected by the alkalinity of the surrounding concrete. Corrosion starts when that protection is lost through carbonation of the cover or chloride at the bar surface, and it propagates where oxygen and moisture are available, which is why persistent wetting at roof edges and parapets is so damaging [4]. Indian durability provisions are found in IS 456:2000 through exposure classes, minimum cover and minimum cement content, and an old structure built to earlier practice may not satisfy them [5]. Reinforced-concrete jacketing is attractive in India because materials and labour are familiar and because it raises strength, stiffness and fire resistance together. Júlio *et al.* [6] assess jacketing of columns with attention to construction details: anchorage of the added bars, preparation of the old surface, stirrup spacing, temporary shoring and placement of new concrete. The significance is that a jacket is not defined by its dimensions alone; the strength gained depends on the interface and the load-transfer detailing.

C. Corrosion and Strengthening of Steel

IS 800:2007 is the governing Indian code for general steel construction in the limit-state format [7]. It has no section devoted to the assessment of corroded members, so the engineer must reduce the section properties and then apply its member checks to the reduced section. Kayser and Nowak [8] combined corrosion location and rate with structural analysis of corroded steel-girder bridges and found that capacity declines fastest for failure modes that depend on thin elements, particularly in compression, so that the governing check for an aged member may differ from that for a new one. Zhao and Zhang [9] review FRP-strengthened steel structures and identify bond-slip modelling and stability of strengthened members as research needs.

D. Testing, Loads and Detailing Standards

Rebound hammer and ultrasonic pulse velocity give indirect, comparative indications of concrete quality, whereas cores tested to IS 516 (Part 4) give direct but local strength [10]. For existing steel the essential data are the actual section dimensions, remaining thickness and grade, for which IS 2062 [11] and IS 808 [12] define the grades and rolled-section properties. Loads are taken from IS 875 Parts 1 to 3 [13]–[15], seismic criteria from IS 1893 (Part 1) [16], and ductile detailing from IS 13920 [17].

Three observations follow. First, the codes and guidelines agree on the sequence of assessment but leave the quality of the evidence to the engineer. Second, research on jacketing and on corroded or strengthened steel is strong on mechanisms but weak on how an in-service project should document its decisions. Third, most sources treat concrete and steel separately. The combined treatment attempted here is a methodological comparison and not a claim of new structural theory.

III. METHODOLOGY

A. Documentary Case-Study Approach

The study is a comparative, qualitative case-study analysis supported by transparent illustrative calculations. It involved no new site measurements or tests. Project facts were taken only from the files supplied by the first author: for the hostel, an architectural 3D view, sheet 1 of 2 of the general arrangement drawing, a model-input report and three site photographs, together with the author's reported project history; for the gantry, a screenshot of an ETABS model and one site photograph. Standards and publications were checked against official catalogue or publisher records.

B. Assessment-to-Retrofit Workflow

The workflow adopted for both cases is shown in Fig. 1. The decision to strengthen depends on the outcome of the analysis of the existing structure, and the strengthened structure is verified by re-analysis and, if it fails, the scheme is revised.

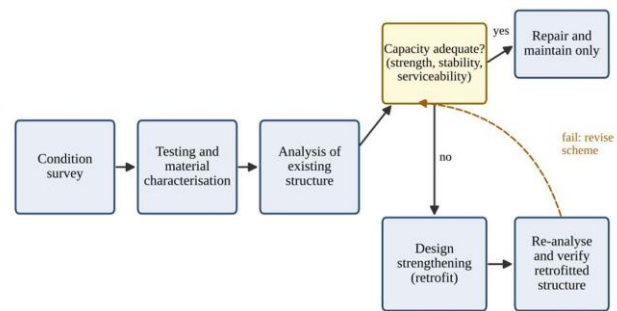


Fig. 1. Assessment-to-retrofit workflow adopted for both case studies

C. Evidence Classification

Every project-specific statement is tied to one of the evidence classes in Table I, so that a reader can see what is established, what is reported and what is assumed.

TABLE I. EVIDENCE LABELS USED IN THE CASE STUDIES

Label	Meaning
Verified from record	Explicitly present in a supplied drawing or report
Observed in photo	Visible in a supplied photograph
Reported, not verified	Stated by the author but not documented in the files
Calculated	Derived transparently from stated inputs
Assumed for illustration	An input chosen to demonstrate the method; not project data
Recommended, not performed	A proposed investigation or action
Not available	Required evidence was not supplied

D. Adoption of Material Properties

Material properties follow a hierarchy: test results first, then original drawings and certificates, then conservative assumed values with a documented basis. M20 concrete and Fe 500 reinforcement appear only as labels in the hostel model, with no documented basis, and are therefore treated as provisional. For the gantry no grade is available, and the illustrative calculations use E 250 steel (yield strength 250 MPa) as an assumed value.

IV. CASE STUDY I: RCC HOSTEL BUILDING

A. Building and Available Records

The first case is the boys' hostel at Al-Kabir Polytechnic, Village Kapali, Block Chandil, Saraikela-Kharsawan, Jharkhand. The drawing title block identifies the project as the renovation of the hostel for the Minority Welfare Department, Government of Jharkhand, with a consultant in Jamshedpur [verified from record]. The age of more than 25 years, the lack of regular use, an audit of member dimensions, a finding that the existing structure failed the analysis, and a retrofit by RCC jacketing of selected foundations, beams and columns with slab repair are all reported by the author but not independently verified. The general arrangement drawing shows an L-shaped plan with six rooms of 5.00 m × 3.50 m, a canteen of 14.30 m × 9.30 m and a kitchen of 9.30 m × 6.00 m. The drawings are architectural: no member sizes, reinforcement or foundation details were available.

B. Visual Condition and Testing Status

Fig. 2 shows an RC frame with regular bays, band beams, plastered infill panels and a parapet. The plaster is discoloured, with dark staining along the band beams and parapet that is consistent with persistent wetting and biological growth; plants are visible on or near the parapet, and the steel window shutters show rust staining [observed in photo]. The photographs do not show crack widths, delamination, exposed reinforcement, cover or concrete strength. The staining justifies inspection of the roof drainage, waterproofing and parapet joints, but it does not prove that the reinforcement behind the plaster has corroded.



Fig. 2. External elevation of the hostel showing weathering, staining and vegetation (photograph supplied by the author; date and orientation not recorded)

The author states that no physical tests were performed. No rebound-hammer, ultrasonic-pulse-velocity, core, cover-meter, carbonation, chloride, half-cell or soil results exist, so no test is classed as completed. The recommended sequence is: confirm geometry; inspect roof and drainage; map cracks and sound the concrete; run cover and bar-location surveys; use rebound hammer and pulse velocity for screening; select cores and chemical tests from the screening; investigate foundations where the load path is in doubt; and update the model with verified inputs [recommended, not performed].

C. Review of the Structural-Model Inputs

The model-input report lists IS 456:2000 for concrete, IS 875 (Part 3) for wind with a basic speed of 47 m/s, IS 1893

(Part 1):2016 for response-spectrum analysis in seismic Zone II on medium or stiff soil, response reduction factor $R = 3.0$, importance factor $I = 1.0$, a building height of 12.85 m, and statements that second-order effects were not carried out and no ductility criteria were applied [verified from record, as quoted]. Three findings emerged from reviewing these inputs.

Configuration. The narrative describes a ground-plus-one (G+1) building and the photographs show two storeys, whereas the model lists plinth, first, second, roof and mummy groups at 12.85 m. The author clarifies that the retrofit model was prepared for a ground-plus-two (G+2) design configuration, that is, with provision for one additional floor [reported, not verified]. The model therefore represents the proposed scheme and not the building as it stood, and any statement that the existing structure “failed” must be read against that difference.

Imposed loads. The report lists imposed loads of 1.5 kN/m² for the floors and 1.4 kN/m² for the roof. For a hostel, IS 875 (Part 2) gives 2.0 kN/m² for living rooms, bed rooms and dormitories and 3.0 kN/m² for corridors, passages and staircases [14]. The model values are therefore lower by 25 percent in rooms and by 50 percent in corridors and stairs [calculated]. This is a verification item and not necessarily an error, since the lower value may represent a particular zone or an area-reduction rule, but the basis is not recorded, and imposed load enters both gravity demand and seismic weight.

Wind forces. The reported storey wind forces sum to 705.96 kN in the X direction and 561.00 kN in the Y direction. With tributary widths of 32 m and 27 m and a height of 12.85 m, the average pressures are about 1.72 and 1.62 kN/m². For a basic speed of 47 m/s the dynamic pressure $0.6V^2$ is about 1.33 kN/m², and force coefficients of 1.2 to 1.3 give 1.6 to 1.7 kN/m², so the reported forces are of the right magnitude [calculated, plausibility only]. The export contains no member design ratios, drift, joint or foundation-bearing results, so the reported failure of the existing structure cannot be reproduced.

D. Illustrative Retrofit Calculations

In the absence of project member forces, the calculation sequence is demonstrated with assumed inputs, which are not project data and must not be quoted as measured or as-built values. The demand–capacity ratio (DCR) is

$$DCR = S_d / R_d \quad (1)$$

where S_d is the design action effect and R_d the design resistance computed with the adopted properties. For a short column under predominantly axial load, IS 456:2000 clause 39.3 [5] gives

$$P_u = 0.4 f_{ck} A_c + 0.67 f_y A_{sc} \quad (2)$$

where f_{ck} is the characteristic concrete strength, A_c the net concrete area, f_y the steel yield strength and A_{sc} the longitudinal steel area. The assumed column is 350 mm × 500 mm with eight 16 mm Fe 500 bars and a factored axial demand of 1,600 kN. Two concrete strengths are considered: 20 MPa (nominal) and 13 MPa (deteriorated scenario). The assumed jacket is 75 mm per face of M25 concrete with eight 16 mm bars, and a factor of 0.8 is applied to the jacket contribution. Results are in Table II.

TABLE II. ILLUSTRATIVE RCC CHECKS (ASSUMED INPUTS; NOT PROJECT RESULTS)

Check	Existing	Retrofitted
Column P_u , 20 MPa	1,926 kN; DCR 0.83	Not computed
Column P_u , 13 MPa	1,440 kN; DCR 1.11	3,059 kN; DCR 0.52
Footing pressure (allowable 120 kPa assumed)	165 kPa; ratio 1.38	126 kPa; ratio 1.05 (fails)
Drift, flexure, shear, joints	Not available	Not available

A column that passes with the nominal grade fails if the in-situ concrete is weaker, which is why cores must precede any capacity statement. For the footing, an assumed 2.80 m square footing carrying the implied load of 1,294 kN gives 165 kPa; enlarging it to 3.20 m gives 126 kPa, still above the assumed 120 kPa allowable, and about 3.30 m would be required. Enlargement alone therefore does not cure the assumed deficiency, and flexure, shear, punching and the new-to-old interface would still need checking. The axial-only formula and the 0.8 factor are simplifications; a real design needs the interaction check with moments and slenderness, interface-shear design, anchorage and joint detailing.

E. Retrofit Measures and Quality Assurance

The retrofit selection follows the diagnosis: waterproofing and drainage correction wherever ingress is confirmed, patch repair where cover has been lost after the cause is dealt with, and jacketing where assessment establishes a capacity deficiency. For jacketing, the design must address load transfer (the jacket carries its share of existing load only if the construction sequence and shoring justify it), composite action at a roughened and cleaned interface with designed dowels, continuity of the added bars through slabs and joints, closely spaced ties near ends and joints for confinement, and the global effect, since stiffer members attract more lateral force and the model must be re-run [2], [6]. Construction should proceed under hold points before concealment, with an inspection and test plan covering baseline survey, extent of concrete removal, reinforcement condition, interface preparation, jacket steel, concrete placement, curing and as-built records.

The priority actions that follow from the evidence are to confirm the building configuration and restrict use where unstable concrete is suspected; control water by clearing vegetation and repairing drainage, waterproofing and parapet joints; complete the missing investigations; reconcile the model with the surveyed structure and re-run the existing-structure checks with corrected loads; and document and verify the as-built jacket and foundation works.

V. CASE STUDY II: STEEL LOADING GANTRY

A. Structure and Available Records

The second case is the steel loading gantry at the Bharat Petroleum Corporation Limited (BPCL) Tata Nagar Depot, Jamshedpur, Jharkhand, which supports the loading of road tankers [reported, not verified]. The supplied evidence is a screenshot of an ETABS Ultimate 22.6.0 model titled BPCL and dated 02.06.26 (Fig. 3), and one site photograph dated 21 May 2026 from its file name. The model shows a steel canopy whose roof is a grid of triangulated trusses on tall columns, with two lower platform decks framed by beams and diagonal members at some supports [verified from record]. The view is a wireframe: section sizes, material, loads, supports and results are not shown, the geometry cannot be scaled, and the native file was not supplied. The photograph shows two persons on a

steel grating platform beside a pump or motor set, one holding a scale against a steel support member. It records that a manual measurement took place, but it shows no measured value, member identifier or condition rating, and it does not establish that the platform belongs to the gantry model. No deficiency in the gantry can therefore be stated.

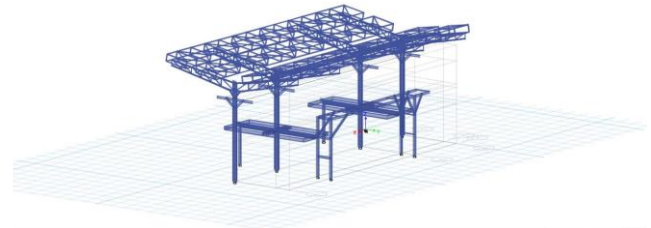


Fig. 3. ETABS 3-D model of the gantry (screenshot supplied by the author; sections, loads and results not shown)

B. Assessment Procedure for a Gantry of This Type

The survey proceeds member by member, recording coating condition, rust grade, pitting and section loss, distortion and local buckling, weld cracking, bolt condition, base-plate and anchor corrosion, drainage paths, and the state of sag rods and bracing. Locations that most commonly lose section are column bases and base plates, purlin flange undersides and web ends, truss joints and gusset plates, sheeting fixings, welds, and platform supports. The investigation comprises material certificates, a dimensional survey compared with IS 808 [12], a thickness survey after cleaning to bare metal, weld and bolt inspection, and coupon tests where the grade is unknown [11].

Member checks apply the limit-state expressions of IS 800:2007 [7] to the reduced section. For a laterally supported section the design bending strength is

$$M_d = \beta_b Z_p f_y / \gamma_{m0} \quad (3)$$

where β_b is 1.0 for plastic and compact sections and Z_e/Z_p for semi-compact sections, Z_p and Z_e are the plastic and elastic section moduli, and $\gamma_{m0} = 1.10$. Wind pressure follows $p_z = 0.6V_z^2$ (N/m²) with the modification factors of IS 875 (Part 3) [15]. The governing combination differs by member: purlins are controlled by dead plus imposed load in gravity, but wind uplift can reverse the flange stresses and leave the compression flange on the unrestrained side, whereas columns and base plates are governed by lateral wind and overturning. For an aged canopy the critical checks typically are base and anchor capacity under uplift, purlin lateral stability under uplift, local buckling of corroded webs and outstands, and connection capacity at truss joints.

C. Illustrative Purlin Example

To show how corrosion changes a member check, an ISMC 125 purlin of 5.0 m span at 2.0 m spacing in E 250 steel is assumed, with section properties from IS 808 (to be verified), a bending demand of 9.04 kN·m, and corrosion that reduces the second moment of area and the section modulus to 65 percent of the original. Strengthening is by 60 mm × 6 mm plates on the flange faces, assumed fully effective (Fig. 4). Elastic section modulus is used for M_d in Eq. (3). Results are in Table III.

TABLE III. ILLUSTRATIVE STEEL PURLIN (ASSUMED INPUTS; NOT PROJECT RESULTS)

Check	Original	Corroded	Strengthened
Moment of inertia (cm ⁴)	416.4	270.7	580
Elastic modulus (cm ³)	66.6	43.3	84.6
M_d (kN·m)	15.1	9.84	19.2
DCR for 9.04 kN·m	0.60	0.92	0.47
Deflection (mm); limit 33.3	18.9	29.0	13.5

The assumed corrosion consumes most of the bending margin (DCR rising from 0.60 to 0.92) and brings the deflection close to the L/150 limit, and the plates restore the margin. This demonstrates the method only; it says nothing about the actual gantry, and stability and connection checks would still be required.

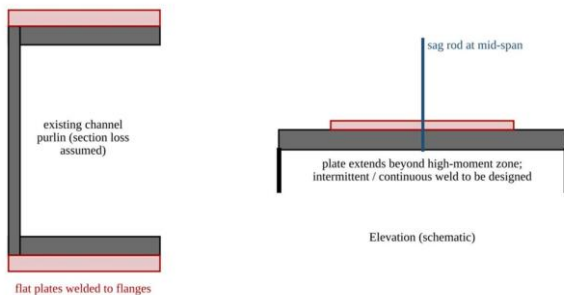


Fig. 4. Schematic of plate strengthening of a corroded channel purlin (concept only)

D. Retrofit Options and Hot-Work Constraints

Cleaning and recoating comes first, because stopping corrosion is cheaper than replacing members. Where the corroded section fails the checks, options include plate or section addition (placed symmetrically, with welds or bolts designed for the shear flow VQ/I), member replacement, reinstatement of missing sag rods and bracing, connection repair, and base-plate and anchor reconstruction. A petroleum depot restricts ignition sources: hot work normally needs a permit and gas-free certification, and work near loading bays may be limited to scheduled shutdowns. These constraints can make bolted plates or cold-applied strengthening, including bonded composites where suitable [9], preferable to welded plates. After retrofit, the model is updated with the strengthened sections; stiffened purlins attract more load, so rafters, trusses and connections must be re-checked.

VI. COMPARATIVE DISCUSSION

Table IV compares the two cases under the evaluation headings of the framework. The comparison is methodological; it does not rank the structures.

TABLE IV. COMPARISON OF THE TWO CASE STUDIES

Aspect	RCC hostel	Steel gantry
System	Moment frame with infill; G+1 reported, G+2 design model	Canopy with columns, trusses, purlins, bracing
Deterioration	Moisture, probable corrosion; photographs only	Atmospheric corrosion, coating loss; no project data
Evidence	Drawings, model report, three photographs, reported history	Model screenshot and one photograph

Tests completed	None documented	None documented
Governing issue	In-situ strength; configuration; loads; foundations	Remaining thickness; stability; base and anchors
Retrofit	RC jacketing, slab repair (reported)	Cleaning, coating, plates, bracing, base repair (options)
Critical detail	Old-to-new concrete interface	Weld or bolt connection
Constraint	Shoring; joint congestion	Hot-work permits; shutdown windows

Concrete deterioration is diffusion-controlled, so moisture, carbonation and cover govern the onset of corrosion, and a concrete member hides its reinforcement. Steel deterioration is surface-controlled, with wetting, coating failure and crevices governing thickness loss, yet the critical locations are often hard to reach. For concrete the dominant uncertainties are in-situ strength and the state of the reinforcement; for steel the grade can usually be bounded, so remaining thickness dominates. In concrete retrofits the interface is the critical detail; in steel it is the connection. Both cases are held back by missing records, and for the hostel the verified deficiencies lie in the evidence and the inputs rather than in the structure, which shows that missing records can be as consequential as visible defects. The following lessons apply to both:

- Diagnose the cause before choosing the repair.
- State the evidence level of every project-specific fact and keep assumed values visibly separate.
- Reconcile the model with the surveyed structure before relying on its results.
- Treat load-transfer detailing at the interface or connection as part of the design.
- Verify the strengthened structure with an updated analysis, not member ratios alone.

VII. CONCLUSIONS

This paper applied an evidence-labelled assessment framework to an RCC hostel and a steel loading gantry. The main conclusions are:

- For the hostel, the drawings and photographs identify the building and show weathering, biological staining and vegetation at roof level, but they do not establish the condition of the concrete or reinforcement. The reported failure of the existing structure and the reported jacketing cannot be reproduced from the records.
- The hostel model represents a G+2 design configuration of 12.85 m, whereas the existing building is reported as G+1, and its imposed loads of 1.5 kN/m² are below the 2.0 and 3.0 kN/m² given for hostel rooms and corridors in IS 875 (Part 2). These should be reconciled and justified. The reported wind forces are of the expected magnitude.
- Illustrative calculations show that column adequacy depends strongly on in-situ concrete strength, and that enlarging an assumed footing from 2.80 m to 3.20 m is

insufficient where about 3.30 m is needed. Tests and a soil investigation are therefore the first priorities.

- For the gantry, the supplied data show only the general arrangement and that a measurement was in progress; no condition, capacity or retrofit result can be reported. The illustrative purlin shows that a plausible section loss can consume most of the bending margin and that plate strengthening can restore it, while hot-work restrictions shape the choice of technique.
- A defensible retrofit file should contain drawings, survey sheets, dated photographs, test reports, the native model, design-check outputs for the existing and retrofitted conditions, strengthening drawings, material and quality records, and a signed review by a responsible structural engineer.

The study is documentary: it included no testing or independent modelling, its calculations use assumed inputs and simplified formulas, and no statement of structural adequacy, safety or code compliance is made for either structure. Future work should obtain the missing records for both cases, develop a validated model of the hostel in its existing and retrofitted states, monitor the retrofitted members over time, and study corrosion-loss patterns and residual capacity in industrial steel canopies using measured data.

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