INVESTIGATION REPORT

ON

THE COLLAPSE OF THE BALCONY

AT 1/F OF THE BUILDING

AT 50 GILLIES AVENUE SOUTH, KOWLOON

ON 21 JUNE 2017

屋宇署
BUILDINGS DEPARTMENT

Buildings Department
October 2017

Introduction

1. On 21 June 2017 at about 2:30 am, the balcony at 1/F of the building at 50 Gillies Avenue South, Kowloon partially collapsed. The Buildings Department (BD) mobilised the Government contractor to carry out emergency works to remove the remaining parts of the collapsed balcony and erect temporary props to support the balconies at 2/F to 4/F of the subject building to ensure public safety.

2. The subject building, located at 46-50 Gillies Avenue South, is a 6-storey reinforced concrete building with occupation permit issued on 19 July 1956. It is a composite building with shops at ground floor and residential flats at upper floors. The partially collapsed balcony at 1/F was 4.8 metre (m) long with a projection of 2.4m from the external wall. It was structurally supported by two cantilevered beams (FB30 and FB35). It had a 50mm drop in structural floor level as compared with the interior and was designed as an unenclosed balcony with a 900mm high parapet on 3 sides (**Annexes 1, 2 and 3**).

Investigation

3. After the incident, the BD has conducted an investigation into the cause of the incident through site inspections, interviews with the occupants, review of approved building records (including minor works submissions), laboratory testing and analysis of samples collected on site and structural assessment of the balcony.

4. From the evidence available, the following findings were revealed:

(a) There was no submission of any alteration and addition works or minor works related to the collapsed balcony. According to the occupants, no building works were recently carried out to the balcony;

(b) Beam FB35 and about half of the balcony slab collapsed with its steel reinforcement bars exposed. Beam FB30 remained in place but spalling, cracks and rusted steel reinforcement bars were noted;

(c) The floor of the balcony was raised with finishes to level with the interior of 1/F. The thickness of the additional finishes was about 50mm;

(d) The approved 75mm thick parapet of the collapsed balcony was covered with additional cement rendering of about 75mm thick;

(e) Aluminium windows were installed on top of the parapet to enclose the whole balcony; and

(f) The balcony was used as a bedroom and placed with furniture and household appliances. Storage of some builder tools was also noted.

Structural Assessment – Cause of Collapse

5. The structural assessment focused on the Structural Performance Factor[1] (Fsp) of Beam FB35. If the Fsp is less than 1, Beam FB35 is considered below the acceptable safety margin.

6. As the structural condition of the building was not in favour of performing destructive testing, laboratory testing of concrete debris and reinforcement segments collected from the scene was conducted. The test results are as follows:

(a) Schmidt Hammer Test[2] on the concrete samples indicated that the average compressive strength of Beam FB35 was 7.0 N/mm^2. The calculated shear strength was 0.31 N/mm^2. The original design compressive strength and shear strength were 2,250 lb/in^2 (or 15 N/mm^2) and 60 lb/in^2 (or 0.4 N/mm^2) respectively;

[1] It is an indicator of the loading capacity of reinforced concrete elements, viz. Fsp(bending) and Fsp(shear) to resist bending and shear of a structural member respectively.

[2] This test is adopted as the concrete debris collected on site was too fragmented and fragile for taking core samples for compressive or shear strength tests.

(b) Carbonation[3] tests on the concrete samples taken from Beam FB35 indicated carbonation of more than 80mm deep which had exceeded the thickness of the nominal concrete cover of 25mm;

(c) Tensile tests on the main steel reinforcement bars of Beam FB35 revealed that the average tensile strength was 276 N/mm^2. The design yield strength was 36,000 lb/in^2 (or 250 N/mm^2);

(d) The cross sectional area of the reinforcement bars had generally been reduced due to corrosion. The 19mm and 16mm diameter bars taken from Beam FB35 were reduced by 12% and 23% respectively; and

(e) Average unit weights of the samples of the additional floor finishes and the thickened parapet rendering were 18.5 kN/m^3 and 18.0 kN/m^3 respectively.

7. Based on the test results on the strength of concrete and corroded steel reinforcement bars, the Fsp(bending) and Fsp(shear) of Beam FB35 when subject to the additional loading in paragraph 4(c) to (e) above are 1.24 and 0.95 respectively, indicating that Beam FB35 is still capable of sustaining the increased loading in bending but is marginally below the acceptable level of safety margin in shear. The Fsp would be further reduced due to reduction of the effective cross sectional area of Beam FB35 caused by concrete spalling.

Factors Contributory to the Collapse

8. The original structural design has been reviewed and found generally in order. The contributory factors to the collapse are:

(a) Declined concrete strength – The compressive strength of Beam FB35 was about 53% less than the original design strength;

[3] The chemical reaction of concrete and carbon dioxide reduces the alkaline protection of concrete, resulting in a condition conducive to corrosion of steel reinforcement bars in reinforced concrete construction that leads to concrete spalling.

(b) Corrosion of steel reinforcement bars – Carbonation in Beam FB35 had led to corrosion of steel reinforcement bars that caused concrete spalling. Thus, the effective cross sectional area of the steel reinforcement bars and concrete had been reduced and the loading capacity of the Beam FB35 was reduced;

(c) Increase in loading – There was 44% increase in dead load on Beam FB35 from the 50mm additional floor finishes, additional 75mm wall rendering and additional aluminium windows; and

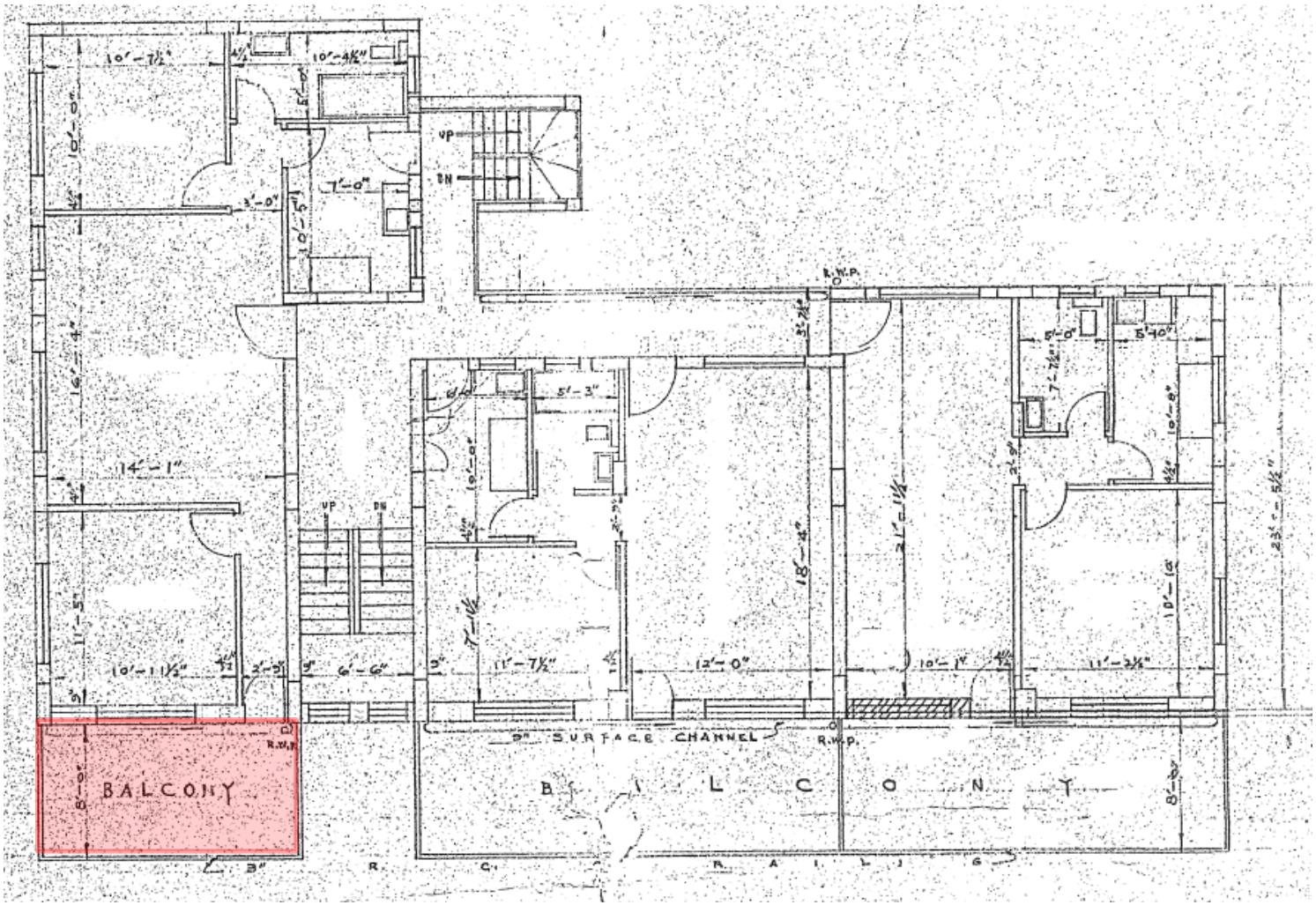
(d) Lack of maintenance – Cracks, concrete spalling and rusted reinforcement bars were noted in Beams FB30 and FB35 on site. It is evident that the building generally lacks maintenance. Without proper maintenance, cracks in Beam FB35 had developed and propagated, lowering the Fsp of Beam FB35.

Conclusion

9. As revealed from the above investigation and structural assessment, the shear strength of Beam FB35 had been reduced due to declined concrete strength, corrosion of steel reinforcement bars and prolonged lack of maintenance. Coupled with the additional loads of the raised floor finishes and rendering on the parapet and the installation of aluminium windows, the collapse of the balcony was triggered by shear failure of Beam FB35.

Buildings Department
October 2017

BULKELEY STREET



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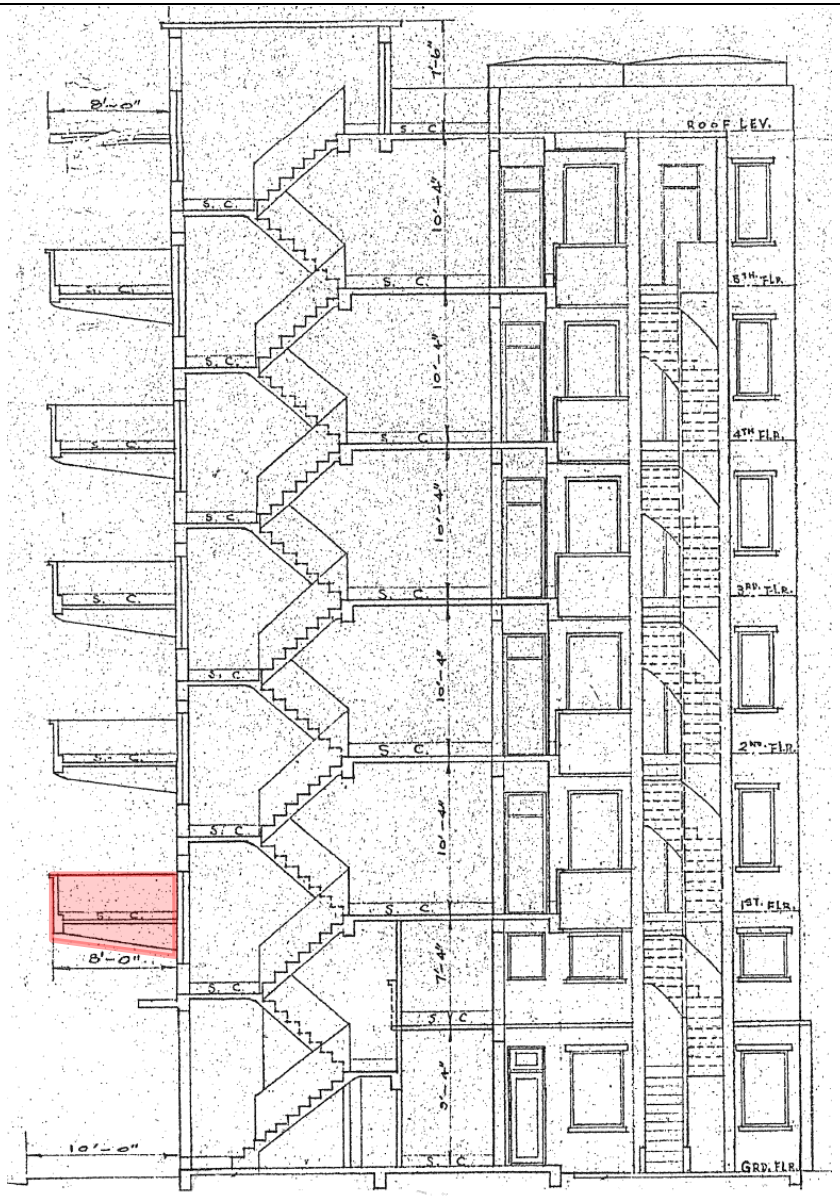
Partially collapsed balcony

GILLIES AVENUE SOUTH

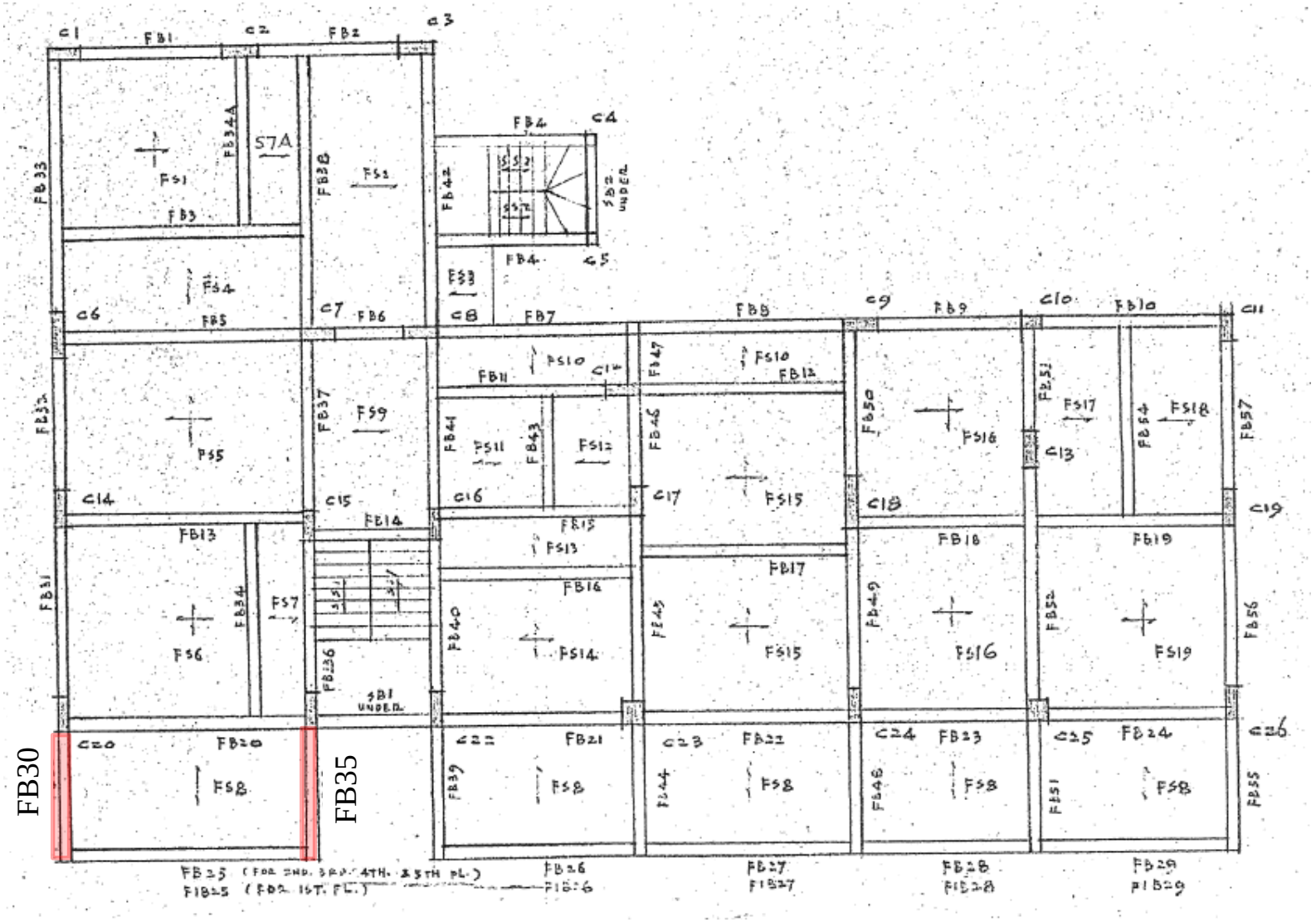
屋宇署 BUILDINGS DEPARTMENT	Approved First Floor Plan	
	46-50 Gillies Avenue South, Kowloon	

GILLIES AVENUE SOUTH



Partially collapsed balcony

屋宇署 BUILDINGS DEPARTMENT	Approved Section	
	46-50 Gillies Avenue South, Kowloon	



屋宇署 BUILDINGS DEPARTMENT	Approved First Floor Framing Plan	
	46-50 Gillies Avenue South, Kowloon	