RPA
Railway Procurement Agency

METRO NORTH
ORAL HEARING
Stage 2A Preliminary Building Response Report
Rev3_Part3_PartH

Project Title: Dublin Metro North			Sheet No: 2
Subject: Building Response adjacent to Griffith Avenue Stop			Calc No: 4
Job No: B0307000			File: City Centre
Made By: BA	Date: 08/02/09	Revised By:	Date:
Checked By: AL	Date: 09/02/09	Checked By:	Date:

Horizontal Stain

The average horizontal strain exerted on the structure has been calculated as the change in length of the building brought about by horizontal ground movements divided by the original length of the building.

The formula used is as follow:

$$\varepsilon_h = \left(\frac{S_{ha} - S_{hb}}{L_o} \right)$$

Where:

- S_{ha} is the horizontal movement calculated at the nearest edge of the building to the underground structure that caused the settlement (indicated as point A in the figures 1,2 and 3)
- S_{hb} is the horizontal movement calculated at the furthest edge of the building to the underground structure that caused the settlement (indicated as point B in the figures 1,2 and 3)
- L_o is the original length of the building, calculated as follow:

  L_o=L1+L2 (see Figures 1 and 2)

  $L_o=L_1^h+L_2^h$ (hogging zone), $L=L_1^s+L_2^s$ (sagging zone), (see Figure 3 top drawing)

  L_o=L (see Figure 3, bottom drawing)

The horizontal movement has been calculated as follow:

$$S_h = K \times S_v$$

Where:

- K is the ratio of horizontal to vertical movement (dependant on the stiffness of the surrounding soil).
- S_v is the vertical movement.

Vertical movements have been obtained by trigonometry between known data points from the relevant Stage 1 Predicted Settlement Contour Drawing (see Figures 1, 2 and 3).

The ratio of horizontal movement to vertical movement (K) has been determined based on the findings of Clough & O'Rourke (1990), where for stiff to very hard clays, it is suggested that horizontal movements are equal to or will exceed the vertical movement by a ratio of 1.0 to 2.5. Given that the Dublin glacial till is much stiffer than the majority of stiff to hard clays used in the database and assuming a high horizontal support stiffness for Metro North excavations, it has been assumed that a horizontal to vertical movement ratio of 1.0 to 1.0 is appropriate for the glacial till. For excavations in sand, the horizontal to vertical movement ratio is suggested to range from 0.8 to 1.5. For the Stage 2A assessment a value of horizontal to vertical movement ratio of 1.0 has been assumed for very dense granular material and a ratio of 1.5 assumed for loose to medium dense sands.

CALCULATION SHEET

JACOBS

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Bending Strain

The Bending Strain has been calculated by treating the building as an idealised beam of span L (length of the building) and height H (height of the building) deforming under a central point load to give a maximum deflection. The expression applied to calculate the bending strain is presented in the general form:

$$\frac{\Delta}{L} = \left(\frac{L}{12t} + \frac{3EI}{2tLHG} \right) \varepsilon_b$$

Where:

- H is the height of the building
- L is the length of the building
- E and G are respectively the Young's modulus and shear modulus of the building
- I is the second moment of area of the equivalent beam (i.e. $H^3/12$ in sagging zone and $H^3/3$ in hogging zone)
- t is the furthest distance from the neutral axis to the edge of the beam (i.e. H/2 in the sagging zone and H in the hogging zone)

The difference in the position of the neutral axis is related to the restraining effect of the foundations. For buildings in the hogging zone the neutral axis has been taken to coincide with the lower extreme fibre of the beam, i.e. the bottom of the structure. For buildings in the sagging zone mode, however, the neutral axis has been assumed to remain in the middle of the beam. Thus, the bending strain in calculated taking into account the position of the building, whether it is in the sagging zone or in the hogging zone.

For the case where the building is partially located in both hogging and sagging zones, separate analyses will be conducted to determine the bending strain attributed for each potion of the building. The larger bending strain between the two sides will be used to define the damage category of the building.

Building dimensions and their position relative to the adjacent Stop box have been obtained directly from topographical survey drawings. In the absence of any topographical survey OS mapping has been used. The predicted settlement contour drawings have been used to identify sagging and hogging zones and retrieve changes in vertical movement for each building identified.

The follow criteria have been applied to define the sagging and the hogging zones for each building considered:

- The settlement trough of the Stop box has been approximated by straight lines of same gradient that connect between subsequent contour points.
- Buildings with the edges confined within two consecutive contour lines are subjected to the horizontal strain only.
- Buildings crossed by one settlement contour line are subjected to both horizontal and bending strain (sagging or hogging).
- Buildings crossed by two settlement contour lines are subjected to both horizontal and bending strain (sagging, hogging or both).

CALCULATION SHEET

JACOBS

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In order to determinate whether the building is in the sagging or hogging zone, the settlement contour lines crossing the building and the two directly adjacent either side of the building have been considered (Figures 1 to 3). The building is considered to be in the sagging zone if the distance between the first and the second predicted settlement contour line is larger than the distance between the second and the third and vice versa for buildings in the hogging zone. When the building is crossed by two settlement contour lines, the building is considered to be within the sagging zone if the distance between the two lines is decreasing moving away from the box. Conversely, if the distance between the contour lines increases then the building is considered to be located within the hogging zone. Where two or more contour lines cross the building the closer of the two will be used to assess the maximum bending strain of the building. In this case, the length of the building will be taken to equal to the distance between the two contour lines.

- The structural characteristics of the buildings were obtained from the relevant building characterisation survey and from site walkover notes. In particular the structural characteristics required for the calculation are building height and the ratio between the Young's modulus and the shear modulus (E/G), which has been assumed as 2.6 for masonry buildings and 12.5 for framed buildings.

CALCULATION SHEET

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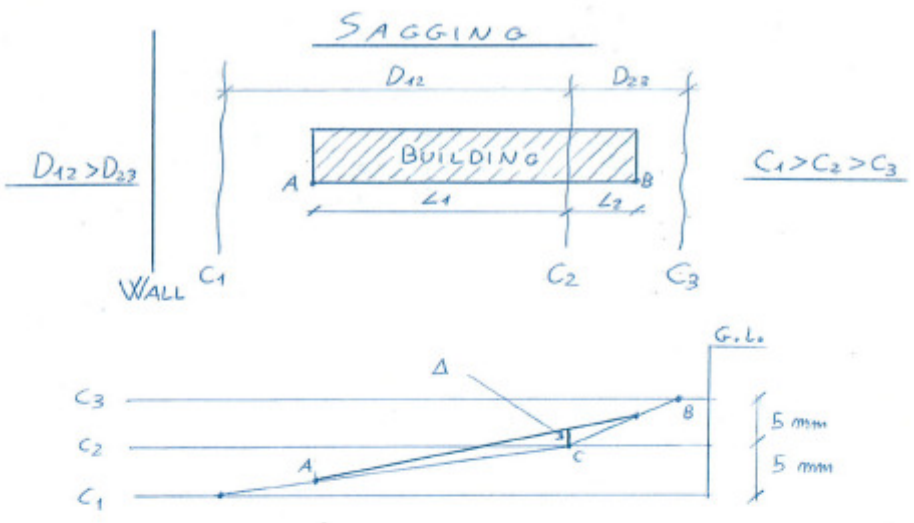

Figure. 1 – Assessment of Buildings within the Sagging Zone

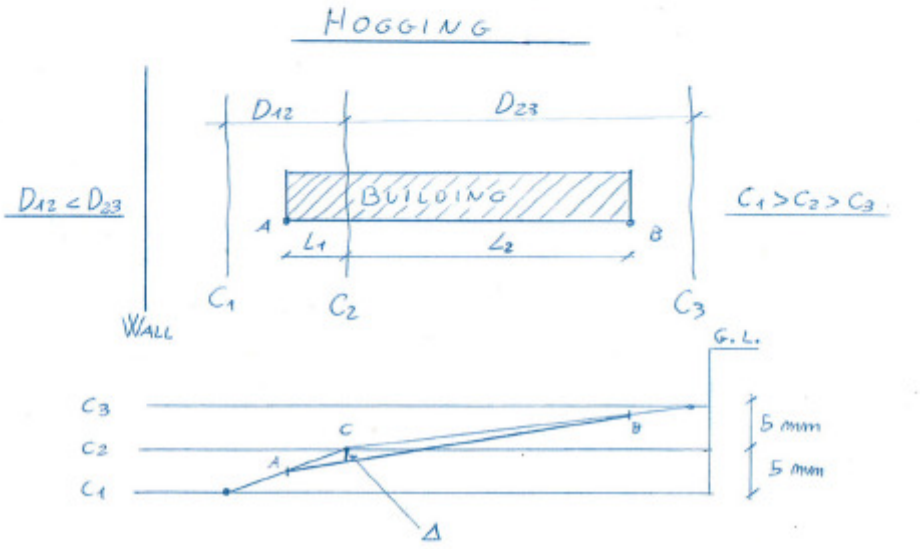

Figure. 2 – Assessment of Buildings within the Hogging Zone

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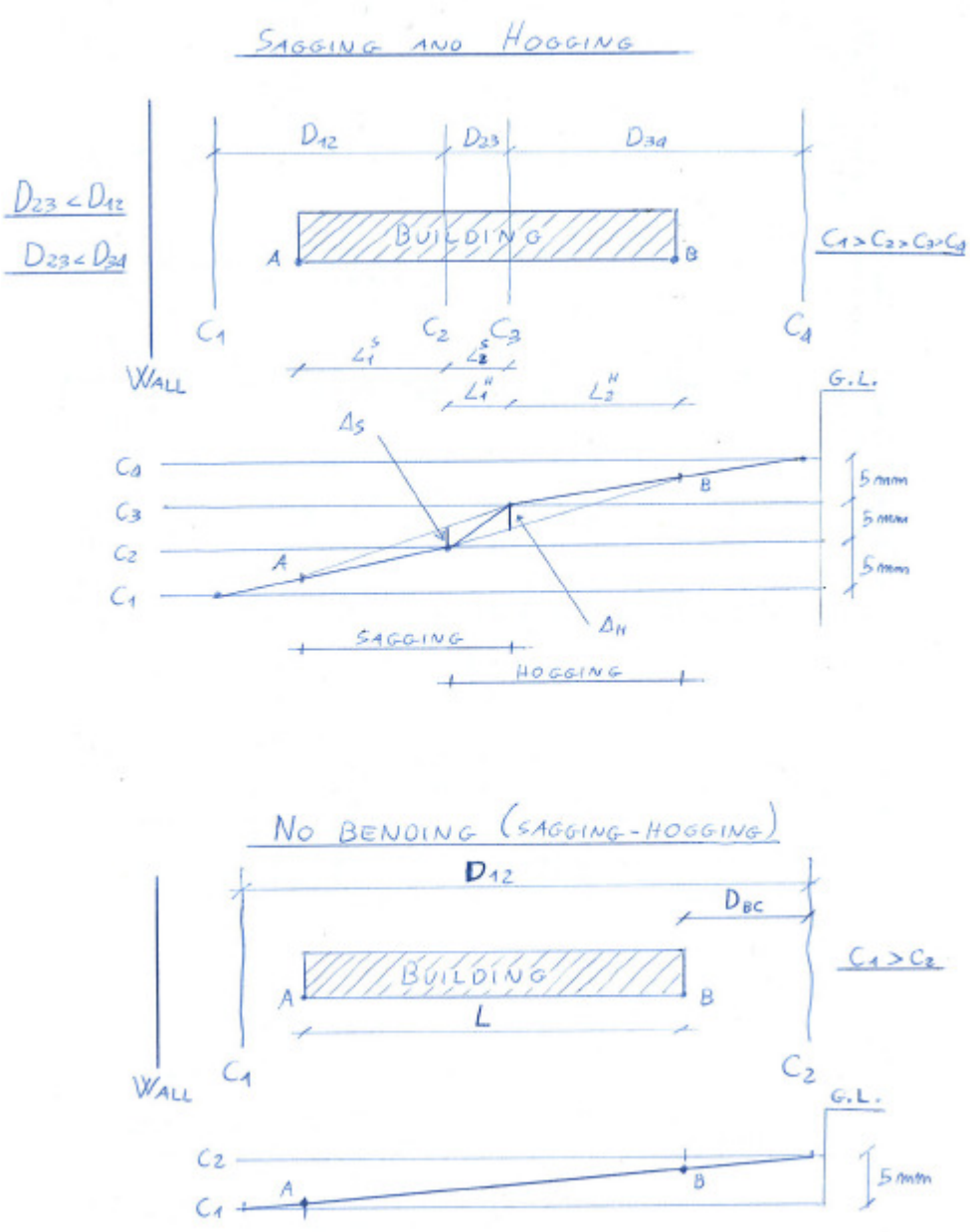

Figure. 3 – Assessment of Buildings within the Sagging and Hogging Zone

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