MetroLink

Transport Infrastructure Ireland

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1. Introducing CIRIA C796

The CIRIA guide C796 ***Assessing the Impacts of Construction -Induced Ground Movements on framed buildings*** has been prepared to provide guidance on the prediction, assessment and mitigation of damage to buildings associated with construction induced ground movements. This includes ground movements associated with construction activities such as deep basement excavations, tunnelling and dewatering. In particular, the document was intended to provide a clear strategy for assessing the impacts of these ground movements on modern steel and reinforced concrete framed buildings, as well as a variety of cladding systems.

Prior to the publication of C796, the assessment of the impact of construction induced ground movement on existing structures was undertaken based on limiting tensile strains, building damage classifications based on observed crack widths and ease of repair for masonry structures in line with various papers published by Burland *et al*, Mair *et al* and New *et al*. The limiting tensile strain classification was originally intended for use with masonry structures and as a consequence C796 was prepared to compliment the above approach and provide further guidance on the assessment of modern framed buildings.

This guide describes the various types of construction related ground movement as well as sources of information and guidance on the assessment of buildings subject to ground movement. Using this information,, a methodology for the assessment of the impact of ground movement on framed structures and cladding has been developed. The methodology is used to modify the greenfield displacement profile taking account of the relative stiffness of the building frame, the foundation type and the ground conditions. In line with Rankin's acceptance criteria provided the deflection is less than 10mm and the vertical displacement gradient is less than 1:500, the risk of damage is deemed negligible. If either of these criteria is not satisfied, following the completion of refined geotechnical and soil-structure interaction modelling, the structure frame should be reviewed by a suitably qualified structural engineer and the cladding system should be assessed by an appropriately qualified façade engineer.

Assessment Methodology

The detailed assessment methodology outlined in C796 is broken down into 5 steps. The first step involves the determination of greenfield displacements associated with tunnelling and station box excavations. Ground movements associated with excavations are calculated in line with CIRIA C760 Guidance on Embedded Retaining Wall Design whilst the settlement trough associated with tunnel construction is assumed to follow a Gaussian distribution. The next step in the assessment involves the modification of the greenfield settlement trough taking account of the stiffness of the building structure and the ground conditions beneath the structure being assessed. The guide draws on work that has been undertaken over the past 20 years to develop the tensile strain approach by modifying the deflection ratios and associated horizontal building strains calculated in step 1 taking account of the relative stiffness between the structure and the underlying soil.

The relative stiffness parameter is a function of the bending stiffness of the building structural frame, the soil stiffness and the geometry of the building. The guide identifies which of four approaches to adopt when calculating the relative stiffness depending on the type of building foundation – shallow footings, rafts or piles. Information is also provided in the guide on four ways to determine the actual building stiffness depending on whether an upper or lower bound stiffness is to be adopted in the assessment. The lower bound will yield a settlement trough similar to the greenfield settlement whilst an upper bound will provide a significant improvement on the shape of the settlement trough i.e. a trough which is more shallow compared with the greenfield trough. Once the relative stiffness parameter has been determined, a modification factor can be determined from published papers based on the work mentioned above which can then be used to determine the modifications to the settlement trough.

At step 3 the modified displacement profile is compared against the acceptance criteria set out in a paper by Rankin in which the building slope and maximum deflection are compared against the criteria for risk category 1 i.e. maximum building slope of 1:500 and maximum building settlement of 10mm. In the event that these criteria

are not satisfied, the assessment moves to Step 4 and will require the input of a competent experienced structural engineer. At this stage a distinction is made between framed structures with moment resisting connections and frames with pinned connections. Frames with moment resisting connections will need to be subject to a frame displacement method with assessment made of the impact of the additional moments on the structural connections. Frames with pinned connections will need to be assessed using the Rankine risk categories which dictate the appropriate contingency measures.

The final step of the assessment process considers the impact of the revised ground movement profile on the cladding system and will require an assessment to be undertaken by a competent and suitably qualified façade engineer.

2. Effect of tunnelling movements on facades.

Putting established industry guidance in perspective

Guidance on building responses to ground movement has historically been based on experience gained from studies of masonry buildings that have been subjected to movement. More recent guidance deals with framed buildings, and facades to some extent. However, the guidance focuses mainly on ground movement prediction and structural responses, with levels of potential structural damage. The guide, CIRIA C796[1], for example, deals with facades broadly and generically and directs that, where a potential issue arises in respect of the façade, a façade expert should be consulted. Consistent with this, TII has engaged the services of a façades expert.

Modern facades vary significantly in nature and so their capabilities of accommodating movement of the supporting structure, vary significantly too. It is not feasible to establish standard or typical movement limits that will ensure that the facades are not significantly affected. Even if the same façade system is used on two buildings, the capacity for the façade to accommodate movement induced by excavation or ground movement from tunnelling will differ from one building to the next because the façade geometries will differ and the supporting structures' expected movements, will differ. Both these aspects greatly influence the façade capacity to accommodate movement, amongst many other variables.

Each façade is unique and so must be studied for implications of movement on a case-by-case basis

On the Metrolink project, this is recognised and initial assessments of facades are being carried out to establish the appropriate study required for the facades of all buildings. This assessment will identify facades for which detailed studies are required, advance to a Phase 3 assessment a class D special building, and for which detailed studies are not required, to understand the implications of the movement. Based on the findings of these, any foreseen implications will be presented to the building owners. If any mitigations measures are deemed to be necessary to reduce risk of impacts on the facades, the relevant options will be discussed and chosen with the building owner. The mitigation measures will be implemented at the appropriate time and if required, repairs and remediation work will be carried out

It should be appreciated that seldomly is direct intervention with the façade fabric needed and when needed this can an will be minimized and localised

The real mitigation of impact is achieved through the detailed studies of façade movement capacity in relation to the predicted tunneling movement .

A detailed study of a facades' capacity to accommodate the tunnelling movements will involve the following.

1) A detailed façade visual condition survey will be undertaken by a surveyor to establish the Pre-Tunnelling condition of the façade.
2) Gathering the necessary information to understand the façade in detail. This will consist of:
    a. Detailed façade design drawings and specification
    b. Detailed review of the Operation and Maintenance Manuals of the building to supplement the drawings and specifications in understanding the movement capacity of each system. Industry references for movement capabilities of each system will be adopted as baseline assumptions in lieu of sufficient information mentioned above.
3) Establish actual expected building movements (sway and defections) of the primary structure and translate the structure movement into façade movement – the response of the façade.

[1] CIRIA C796 Assessing impact of construction-induced ground movement on framed buildings

4) Check if there is sufficient movement capacity within the façade to accommodate the additional movement due to tunnelling.

If results show that there is sufficient additional movement capacity, then no action needs to be taken.

If the results indicate that there is insufficient additional capacity available, the mitigation measures agreed with the building owner, will be implemented via the building Trigger Action Plan.

Mitigation measures range fro actions taken with the tunnelling. Moderation of the structures response to the tunneling can be implemented and also certain facade interventions are feasible that will be very system specific.