Behavior of Cast-in C-Channels Anchor in Precast Concrete under Uniaxial Tension Load

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ABSTRACT: The Cast-in C-channel is a small anchoring steel piece used to post-connect different type of elements in precast concrete members, The advantages of implementing the cast-in C-channel is its simplicity to attach to the connecting elements which gives more tolerance between the connected members , in addition to that; its use leads to safe and economical design. Other means of connecting to precast concrete members is by using either post-installed anchoring systems or by fixed steel embedment, which consequently needs drilling inside concrete and sometimes difficult to be performed due to the presence of steel reinforcement inside the concrete members. The proposed system is composed of a C-shaped channel that can be either cold-formed or hot-rolled, and a hammer shaped head bolts with nuts and washers to hold the connected piece, the C-channel is preinstalled in concrete before casting and its anchorage with concrete is done by various ways , such as welding or by using riveting studs connected to the channel, or by inserting a small piece of steel at the back of the channel. The objective of this study is to experimentally investigate the ultimate capacity of cast-in C-channel under uni-axial tension and compare its ulitimate load capacity and failure mode with 3-D finite element modeling using plastic-damage constitutive model for concrete. The results of the finite element modelling is conducted using ABAQUS and still under preliminary stages.

1 INTRODUCTION

The Cast-in C-channels (Figure 1) is a small anchoring steel piece used to post-connect different type of elements of precast concrete members, The advantages of implementing the cast-in C-Channel is its simplicity to attach to the connecting elements which gives more tolerance between the connected members. In addition, it is used to safe and economical design (Jordfal, 2012). This cast-in channel has a wider use nowadays, and it is used a lot in precast construction like in fixing precast cladding panels to existing structures, and to install electrical and mechanical utilities to concrete members as shown in (Figure 2).

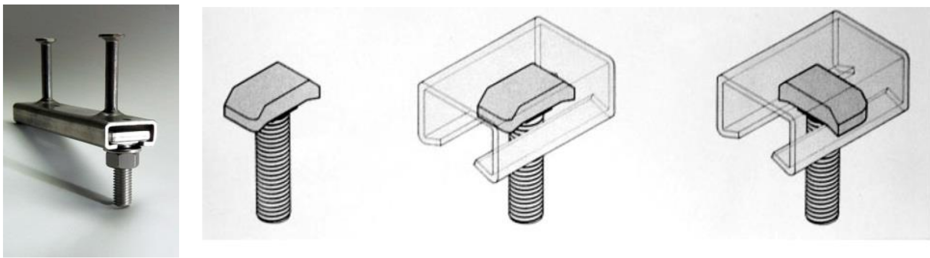


Figure 1: Cast-in Channel with Hummer Head Bolt, and Hummer Bolt installation.

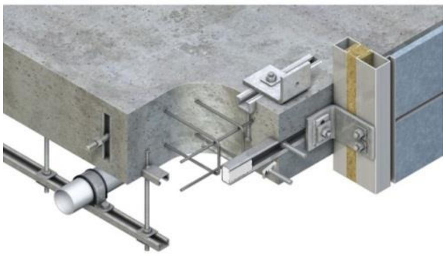


Figure 2: Different uses of the cast-in C-Channel

The failure modes of this type of connections are likely to happen in channel section itself due to load flange yielding as shown in (Figure 3-a), or it might occur due to bolts failure as in Figure 3-b, or due to the failure of the embedded anchor stud steel (Figure 3-c) (ACI- 355.1R-91). The concrete failure mode can be addressed under various load categories, of tension, & shear. The concrete cone breakout failure mode is characterized by the formation of a cone-shaped fracture surface in concrete as shown in (Figure 4) (Eligehausen et al, 2006), the full tensile capacity of concrete is utilized and this type of failure is similar in shape to the punching shear failure. Cone failure have many variables affecting the capacity of the anchor bolts, such as concrete compressive strength, concrete cracking condition (cracked or un-cracked), edge distance, anchor embedment length in concrete and spacing between bolts (Mallée et al, 2013).

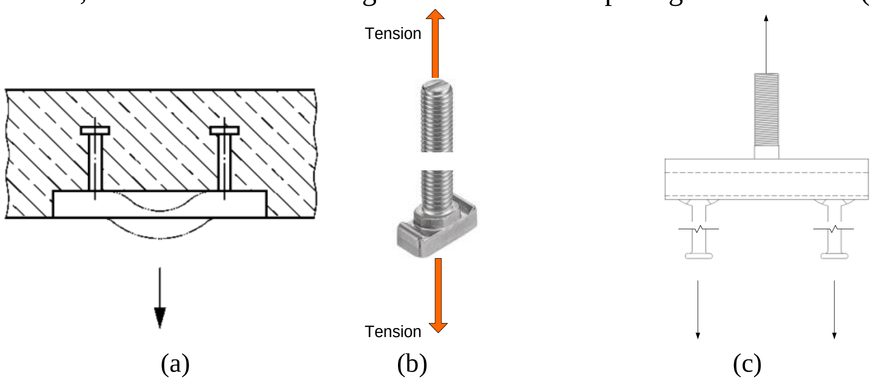


Figure 3: Failure modes of Channel.

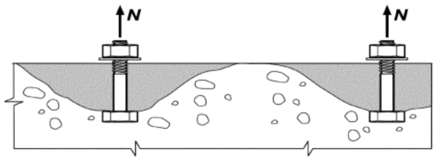


Figure 4: Breakout Failure (Rolf et al, 2006)

An experimental work has been conducted to observe the different failure modes of the cast-in channel embbeded in concrete by subjecting the specimens to uniaxial tension load. In this study, a number of specimens were prepared to investigate the different failures modes. One of these specimen was parpared with a reinforcement bars welded to the channel to avoid concrete anchorage failure as shown in Figure 5. Another specimen was made without the welded rebars to observe anchorage failure. The last specimen was embedded in concrete without studs attached to it to study the effect of the firction between the C-channel and the surrounding concrete. For all of these specimens, the concrete compressive strength at 28-day (fc′) is taken as of 40 MPa. The ultimate capacity of cast-in C-channel under uniaxial tension was investigated experimentally and compare with the 3-D finite element modeling. The finite element modelling was conducted using the comprehensive code ABAQUS. The concrete is modeled by using elastoplastic-damage model developed by Lubliner et al (1989) and extended by Lee and Fenves (1998). Both the cast-in C-channel and concrete are modeled by using 8-node solid elements. In this paper, the hardening and softening in compression of and softening in tension of the concrete are implemented in the FE code based on the results obtained from the experimental testing of concrete specimens under uniaxial compressive and tensile state of stress. The model requires this data in the form of stress-inelastic strain.

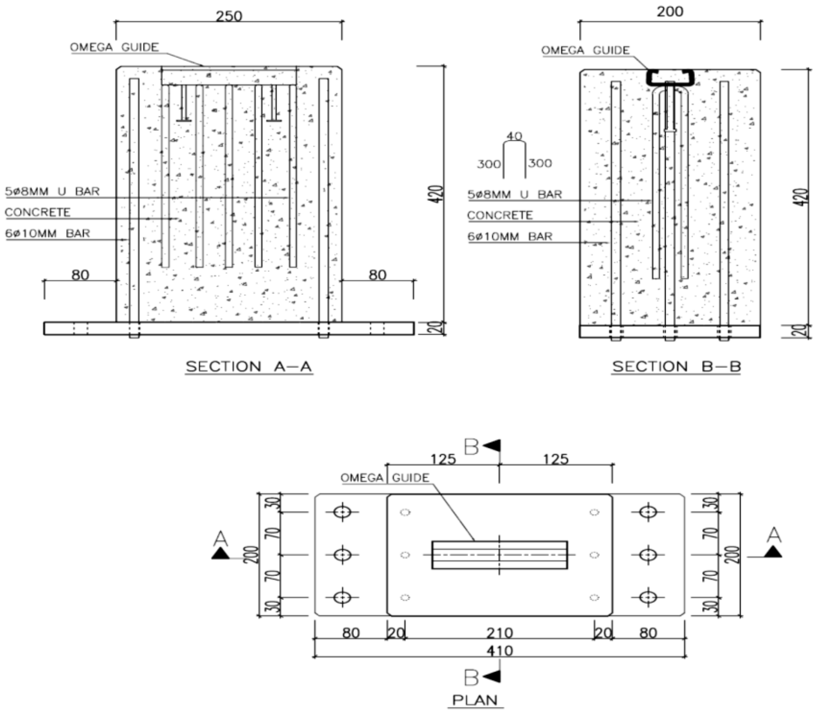


Figure 5: Specimen with reinforcement bars welded to the channel

The study has been motivated by the need to assess the performance and damage propagation in connections in precast structures, an area that has not been addressed at any great length. This preliminary assessment relates to monotonic loading of the connection, with an anticipation to extend the study to cyclic loading of such connections, that would result from seismic loading of the precast structure.

2 FINITE ELEMENT MODEL

The uniaxial stress-inelastic strain data for concrete in compression and tension have been used in the finite element model in ABAQUS. Figure 6 shows one of the specimens subjected to uniaxial tension force and the load-deflection curve was obtained as shown in Figure 7.

Figure.6 Specimen1 under uniaxial tension force

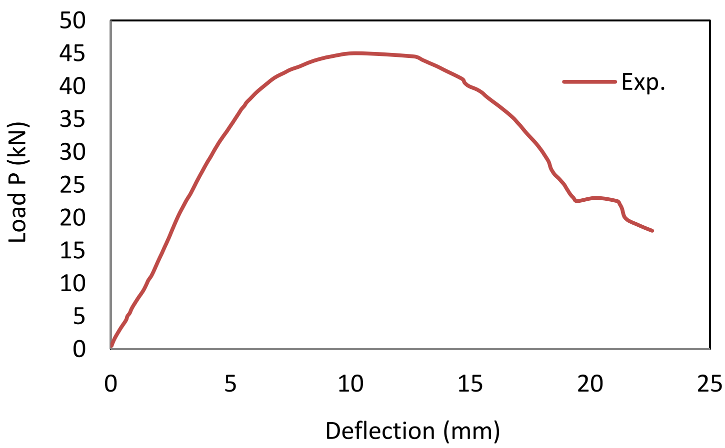


Figure.7 Load- deflection curve of SP1

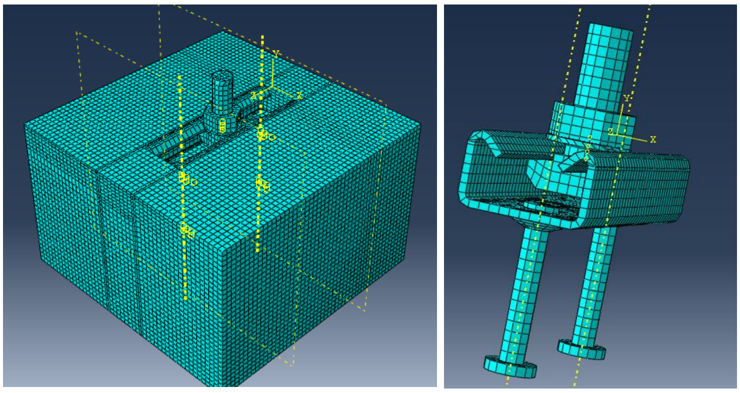
Table 1 shows the plastic damage model parameters implemented in ABAQUS

Table 1. Parameters Used for the Concrete in Plastic Damage Model.

Young's Modulus MPa	Poisson's Ratio	Dilation Angle ψ Degree	Eccentricity ε	f_{bo}/f_{co}	K
30000	0.18	36	0 .1	1.16	0.67

2.1 Meshing

C3D8R 8-node linear brick, reduced integration, hourglass control element is used in modeling of all parts of the model (concrete, C-channel, nuts, bolts, and steel studs). The details of the finite element model of the C-channel, and concrete and its meshing is shown in Figure 8.



a) Full model b) C-Channel

Fig. 8 Finite element model

The interaction between the walls of C-Channel and the concrete is modeled by using general concrete with coefficient of friction of 0.75 and limit of shear stress of 1.33 MPa (as measured) whereas the interaction between the two studs and the concrete was assumed to be perfect bond.

3 DISCUSSION OF RESULTS

3.1 Verification of the model

A comparison of the experimental and numerical results for load-deflection curve of the specimen is shown in Figure 9. The FE results displayed a good agreement with experimental ones. It can be seen that the difference between the finite element failure load of the specimen and experiment failure load is less than 5%. The finite element model showed more stiffness compared to the experiment up to a load of 32 kN.

It can be observed from Figures 10(a) to 10(c) that the failure modes of the specimen and the cracking pattern of concrete due to the uniaxial tension load in the experimental work and finite element analysis are almost similar.

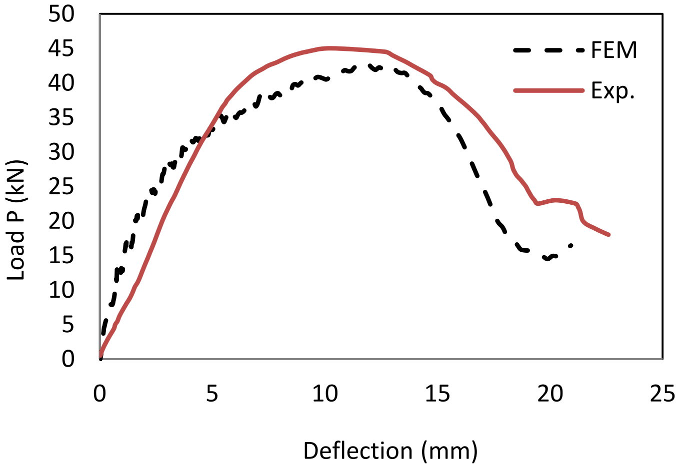
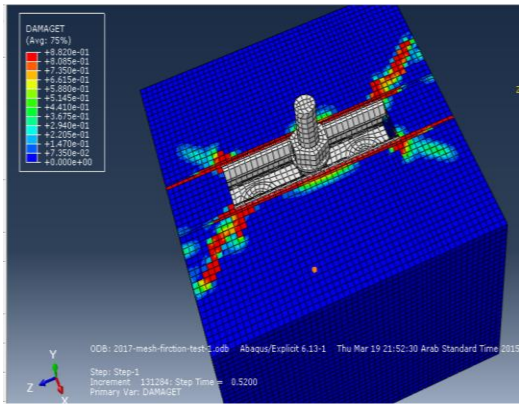
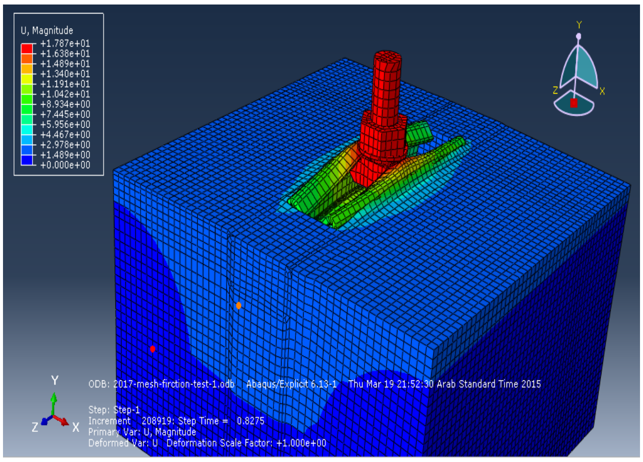


Figure.9 load- deflection curve of the experimental work and finite element analysis

a) Experimental damage and slip of channel related to concrete



b) Finite Element damage



c) Finite Element slip

Figure.10 Failure modes of the specimen in the experimental work and finite element analysis

4 CONCLUSIONS

The objective of this study was to experimentally investigate the ultimate capacity of cast-in C-channel under uniaxial tension and compare its ultimate load capacity and failure mode with 3-D finite element modeling. From the experimental work and finite element simulation the following conclusion can be drawn:

- Damage-plasticity model for concrete in ABAQUS is found to be acceptable in modeling the behavior of the cast-in C-channel embedded in the host concrete.
- A good agreement is found between the crack pattern and the load-deflection behavior using the finite element model and the experimental observation.
- The channel was modelled using non-linear constitutive law.
- The proposed finite element modeling of C-channel embedded in the concrete predicted the failure load with reasonable accuracy and can therefore serve as an acceptable analytical tool for estimation of failure load as well as the failure modes, including cracking at the edges and related slip of channel with respect to concrete. Local yielding of C-channel lips was also predicted.
- The finite element modelling will be extended in the future to cover more key parameters and to be used to develop design guidelines of the cast-in C-channel systems.

5 ACKNOWLEDGMENTS

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