Effect of Loading Frequency on Fatigue Life of Extended Hollobolt in Concrete Filled Hollow Section

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**Abstract.** A difference in frequency of loading during the test may give a different number of cycles to failure, especially at a higher frequency. The difference becomes more evident when higher frequency was applied at the same stress value. The change of frequency should be analyzed to define its effect on the fatigue life of the Extended Hollobolt to concrete filled hollow section. A number of tests are conducted to determine this effect. Frequencies between 0.25 and 5.0 Hz were applied. Analysis of the result indicates that frequency below 3 Hz does not significantly affect the fatigue life of Extended Hollobolt.

**Introduction**

The need to provide mechanical connections from one side only started in a number of engineering fields. Blind fasteners or blind bolts are one of the fastening systems that can be used for installations wherein only one side of the connection can be accessed. For example, blind fasteners can be used to connect the end-plated of a beam to a hollow section as shown in Fig.1. Blind fastener offers the advantage of mechanical installation without the need for welding, in addition to providing sufficient resistance in shear and tension with, potential use in tension applications and in moment connection, uniform high clamping force and vibration resistance [1]. Recent studies describe the behavior of the blind bolt when subjected to increasing monotonic load or cyclic loading. However the behavior of blind bolt subjected to fatigue is still ongoing especially on fatigue life of blind bolt.

![Typical endplate connection to a hollow section](image)

For years, fatigue has been a significant and difficult problem for engineers, particularly for those who design structures such as aircraft, bridges, pressure vessel, and cranes [3]. Recently, A series of fatigue test has been carried out, such as fatigue performance of Extended Hollobolt [4][5].
Fatigue test carried out in laboratory are usually conducted at frequencies between 3 Hz to 160 Hz, depending on the type of specimen and equipment used. In actual structures, however, the frequency of loading may be significantly lower [6].

There is evidence suggesting that testing at an extremely low frequency, which also implies testing with extremely high stress, tends to result in lower fatigue strength than corresponding tests at higher speeds, even without corrosion. This suggests that structures in service would tend to have lower fatigue strength than those related to similar laboratory-tested specimens.

Difference in frequency during testing may give a different number of cycles to failure, especially at a higher frequency [7] [8]. Therefore a series of experiments is carried out to investigate the effect of frequency to fatigue life of Extended Hollobolt in concrete-filled hollow section.

Material

Extended Hollobolt. In this study, Extended Hollobolt (EHB) grade 8.8 with 16 mm diameter is used. This type of blind bolt can only be tightened from one side. EHB is a variation of the Lindapter hollobolt that was developed at the University of Nottingham [9][10][11]. Table I shows the properties of the 8.8 bolts used in the test.

![Fig. 1 The Extended Hollobolt (EHB)[5].](image)

Table 1 Mechanical properties of the Extended Hollobolt

<table>
<thead>
<tr>
<th>Type</th>
<th>Ultimate load (kN)</th>
<th>Yield stress (N/mm²)</th>
<th>Ultimate tensile stress (N/mm²)</th>
<th>Young’s modulus (N/mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extended Hollobolt (EHB)</td>
<td>131.082</td>
<td>813.197</td>
<td>852.39</td>
<td>204.701</td>
</tr>
</tbody>
</table>

Square Hollow Section. A square hollow section with dimensions of 200 x 200 x 12.5 mm was divided to several sections with a length of 500 mm. A hole with a diameter of 28 mm was drilled at the center of the tube face of the square hollow section. Table 2 lists the properties of the square hollow section.

Concrete. The design compressive cube strength was 40 N/mm². The design compressive strength of the 100 mm concrete cubes was determined after seven days from the day of testing.

Table 2 Square hollow section properties

<table>
<thead>
<tr>
<th>Section (mm)</th>
<th>Steel grade</th>
<th>Yield strength (N/mm²)</th>
<th>Young’s modulus (kN/mm²)</th>
<th>Ultimate load (kN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>200 x 200 x 12.5</td>
<td>355</td>
<td>393.404</td>
<td>205.174</td>
<td>125.28</td>
</tr>
</tbody>
</table>
Test Setup

To evaluate the effect of frequency on fatigue life of Extended Hollobolt, a tensile, single pull out tests were carried out. The tensile test utilized a 30 mm thick plate, EHB and a hollow section filled with concrete. The Extended Hollobolts in concrete filled hollow section were set up is shown in Fig. 2. The tests were conducted using a 100 kN capacity servo-control hydraulic system.

Under load control, a constant tensile force was applied (refer with: Fig. 3). A constant applied load has simpler loading history than that of the variable applied load that is more complex and with fluctuating histories. Difference frequencies were applied for a different load/stress ranges. Four different load ranges were used, namely, 90, 70, 60, and 50 kN, which correspond to the nominal stress ranges of 584, 455, 390, and 325 N/mm², respectively.

![Fig. 2 Test set up [5]](image)

![Fig. 3 Loading Hysteresis](image)

Results

**Effect of Frequency.** Table 3 shows that fatigue life at stress 584N/mm² increased by approximately 16% at 1.0 Hz and by 30% at 3.0Hz from 0.25 Hz. These three samples had a similar average loads during the test and exhibited slightly different fatigue life. However, a large difference occurred when a stress range of 454 N/mm² was applied. The large difference in fatigue life at this stress range was due the fact that the stress range increased about 1.4% when higher frequency was used. The increased stress range also occurred when 5.0Hz was applied with the increment of 8% at the same time affected the fatigue life of the Extended Hollobolt. Therefore, in this case, we can conclude that the stress range and fatigue life are affected by the frequency of loading as well as the stress range.
Effect of Frequency on the Failure Mode. The failure mode of the EHB was due to bolt fracture. Fig. 4 shows the Final failure bolts. The difference in the location of fracture between the bolts was due to the position of the bolt during the test, despite the fact that, before the test the load leveled and that the load was working axially. However occasionally in the middle of test, the actuator did not move axially, causing the bolt to have a different location of failure. Nevertheless, the fatigue life of the test bolt was not significantly affected by the final fracture. Overall, the failure mode of the EHB was located in the shank of bolt.

Conclusion
Various loading frequencies were applied to determine their effects on the fatigue life of Extended Hollobolt in concrete filled hollow sections. From tests conducted within the range of 0.25 Hz to 5 Hz, it is shown that frequencies below 3 HZ do not produce variations in the fatigue life of Extended Hollobolt. However a frequency at 5 Hz does affect the fatigue life as the stress range is increased.

For further investigation on the effect of loading frequency onto the fatigue life of Extended Hollobolt, further tests should be conducted at higher frequencies, such as 5 Hz and above. Others effect of loading frequency using different bolt grades, such as 10.9, should also be conducted.

### Table 3 Extended Hollobolt fatigue data for five test loading frequency

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Applied Load (Stress range) kN (N/mm²)</th>
<th>Applied Load (Stress range) kN (N/mm²)</th>
<th>Cycles to failure</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.25</td>
<td>90 (584)</td>
<td>90 (584)</td>
<td>8,025</td>
</tr>
<tr>
<td></td>
<td>70 (454)</td>
<td>70 (454)</td>
<td>20,608</td>
</tr>
<tr>
<td>1.0</td>
<td>90 (584)</td>
<td>90 (584)</td>
<td>9,314</td>
</tr>
<tr>
<td></td>
<td>60 (389)</td>
<td>60 (389)</td>
<td>55,822</td>
</tr>
<tr>
<td>2.0</td>
<td>50 (325)</td>
<td>50 (325)</td>
<td>78,803</td>
</tr>
<tr>
<td>3.0</td>
<td>90 (584)</td>
<td>90 (584)</td>
<td>10,489</td>
</tr>
<tr>
<td></td>
<td>70 (454)</td>
<td>72 (467)</td>
<td>28,331</td>
</tr>
<tr>
<td></td>
<td>60 (389)</td>
<td>61 (396)</td>
<td>58,142</td>
</tr>
<tr>
<td></td>
<td>50 (325)</td>
<td>51 (332)</td>
<td>89,300</td>
</tr>
<tr>
<td>5.0</td>
<td>70 (454)</td>
<td>76 (494)</td>
<td>20,649</td>
</tr>
</tbody>
</table>

Fig. 4 Extended Hollobolt failure mode
Acknowledgment

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References

[2] Information on http://www.lindapter.com/Products/Cavity_Fixings/2/Type_HB_Hollo-Bolt