PERFORMANCE OF SHEAR STUDS IN FIRE
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Introduction

- Technology surrounding fire safety design for composite structures has advanced due to introduction of new insulation materials, the development of computational modeling technology and advanced design methodologies obtained through extensive full scale experiments in fire.
- The structural fire safety calculations have been traditionally based upon prescriptive method according to hourly ratings, on code requirements with respect to standard fires, such as ASTM E119, BS 476 Part 20 or ISO 834. Now both domestic (UK) and international regulations permit design for structural fire safety to be carried out according to performance based concepts.
- A wide-ranging investigation for the in-fire performance of such composite structures has highlighted various local instabilities that are deemed to likely govern the overall fire performance of the structures.

Context of Research

- Analogous to the ULS, the capacity of shear connectors in fire is also required to maintain the function without the premature brittle failure. However, it would be ideal to tolerate against an occurrence of local buckling and a mechanism transition.
- The capacity of stud shear connector embedded in a solid slab was first evaluated by Olligaard, Slutter and Fisher. By the empirical method, an assessment formula of the strength is proposed with an upper limit equal to the tensile strength of the stud, as a function of stud area and concrete properties.

Experimental Programs

- One side of the solid concrete block in the standard push-out specimen was replaced by an electric furnace to provide a 3-sided fire exposure to the steel member. (Figs. 1a & 1b)
- A vertical loading was applied downward from the top of the steel section and the relative displacements were measured from the top of the steel section to the top of concrete slab.
- Lateral movements of the slab base and top of the steel section were restrained. Under the boundary condition, the development of uplift forces in the connectors may be limited.

Fire Tests and Results

- Characteristic properties of the materials are shown in Table 1. Loading was imposed until collapse, at room temperatures (20°C), 30 and 60 minutes after the standard ISO fire.

Analysis of Results

- By modifying Eq. 1 an equation can be proposed to evaluate the stud strength at high temperatures.

\[
Q_{ul} = A_n f_{c,k} SRF_{u} \quad (4)
\]

The specimen consists of a 650 mm length of S355 steel section (150x150x30 UC) connected to a C30 flat concrete slab (400 mm width x 150 mm depth x 500 mm height), using two headed studs of 19 mm diameter x 100 mm depth. (greasing the steel flanges before casting the slab)

Table 1. Properties of Steel and Concrete

<table>
<thead>
<tr>
<th>Property</th>
<th>Steel</th>
<th>Concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield Strength</td>
<td>340 MPa</td>
<td>340 MPa</td>
</tr>
<tr>
<td>Ultimate Strength</td>
<td>427 MPa</td>
<td>427 MPa</td>
</tr>
<tr>
<td>Temperature</td>
<td>25%</td>
<td>25%</td>
</tr>
<tr>
<td>Slump</td>
<td>28 MPa</td>
<td>28 MPa</td>
</tr>
<tr>
<td>Density</td>
<td>7.8</td>
<td>2415 kg/m³</td>
</tr>
</tbody>
</table>

In comparison with the research of Zhao and Kruppa, the observed failure mode of the headed studs in fire is generally alike, but higher strength was recorded due to the lateral restrain at the bottom of the headed studs from the fire exposure surface (Fig. 1c).

Conclusions

- This pilot project was designed to investigate the capacity of headed shear stud at elevated temperatures through the use of a modified push-out test with a solid concrete slab. An electric furnace attached to the test assembly provided three-sided fire exposure to the specimen.
- At room temperature, 30 and 60 minutes of the standard ISO fire, tests were conducted to identify the strength retention properties of the studs. Temperature developments were measured across the steel section and along the stud shank.
- The headed studs failed at elevated temperatures due to shear of the weld-collar/shank interface. An equation was proposed to allow assessment of the residual strength of the stud in fire and this demonstrated a very good agreement with the test results.