DAMAGED COMPOSITE STEEL DECK

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**Introduction**

Composite steel floor slabs are fabricated by securing the steel panels at their supports and then placing an overlayment of structural concrete above the steel panels. Newly placed concrete then is finished to a level-top condition and allowed to cure. Due to the weight of wet concrete, a steel panel will exhibit moderate deflections along its spans, leading to a slab that is thicker near midspan than at supports.

The Steel Deck Institute Composite Deck Design Handbook (1) and the SDI Manual of Construction with Steel Deck (2) both address construction practices and installation loading conditions. An installed steel deck acts as a working platform and is subject to a range of construction loads. After a slab has been finished, it may be found that construction overloads have produced unsightly and unexpected deformations in the steel deck panels. The purpose of this study was to determine the effect of certain overloads on composite slab bending strength.

**Slab Tests**

Composite steel floor deck panels with 2" depth and a 15" corrugation pitch were used for tests in this program. The panels were 8' - 8" long permitting a 96" clear such that third-point line loads across the slabs would lead to a 32" shear span shown in load layout of Figure 1. Test loads were applied through a hydraulic ram equipped with a calibrated load cell. These external loads were transferred into the slab using light steel beams resting on Celotex pads.

Prior to placing any concrete, the bare steel panels were placed in test frame and overloaded in order to produce a permanent set of about 3 inches. This established the “damaged condition” is indicated in Figure 1b. These overloaded panels exhibited permanent buckles in their upper flanges near the transverse load lines but no tearing or any other particular damage was apparent in the tension flange beyond some stretching and panel curvature opposite the compression flange buckled zones. Panels were unloaded, placed into forms and then shored to maintain the 3" deflection as concrete was placed, finished, and cured.

![Figure 1](image)

Slab with two line loads across the width.

Lower surface strain gages were installed on both the top and bottom flanges immediately adjacent to selected webs. These were used to establish steel stresses during loading. Three deflection dial gages were positioned across the slab width at midspan. Incremental test loads, \( P \), then were applied to the cured slabs allowing a load, deflection, and strain record for the full load history up to the failure load.

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1 See end page numbered references.
Composite slab response to test loading may be visualized from the shear segment in Figure 2.

![Slab end segment freebody.](image)

At the right side and immediately right of the load line, a shear component, $V$, is indicated. Here, it represents a shear force from half the weight of the central third of the slab. $P/2$ is the line load. The reaction, $R$, is half the slab weight plus half the applied load, $P$. The right end of the element develops bending resistance during loading. The concrete is in compression with a resultant force, $C$, which acts a small distance below the upper surface. At the same time, the deck develops tension stress reflected in a force, $T$. The position of the $T$ force depends on steel stress distributions over the panel depth and often is within the central third of the steel panel depth. At any rate, $T$ and $C$ are at some distance, $e$, from each other and either may be used for describing a bending resistance.

$$M_r = Ce = Te$$  \(1\)

If two composite slabs are identical except for the slab depth, they will develop similar compression and tension values, $C$ and $T$. If the eccentricity, $e$, were to double, the resisting bending moment, $M_r$, will tend toward doubling.

**Test Results**

Two test slabs were fabricated with attempts to keep them identical. These were to model a field condition in which a composite slab system had been designed to have a 5.25” total depth. But, during concrete placement, the deck was overloaded at a dump point and this led to a midspan measured slab thickness of 8.25” discovered only after the concrete had been finished. These tests were developed to address the as-built composite slab strength.

Each was evaluated following the Composite Deck Design Handbook (1) for slabs without shear studs. Theoretical slab properties were established for a uniform 8.25” total depth and using the recorded properties shown at the top of page 4.
Load deflection results are shown in Figure 3 where numerical load levels, Y, are shown immediately below the associated grid line. X-axis deflection numbers are marked immediately right of their grid line. The following results obtained where P represents the externally applied load.

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum external load</td>
<td>P = 15.85 kips</td>
</tr>
<tr>
<td>Measured first yield load</td>
<td>P_y = 12.46 kips (average from both tests)</td>
</tr>
<tr>
<td>Theoretical bending from 0.6F_s_c</td>
<td>P = 12.35 kips</td>
</tr>
<tr>
<td>Theoretical bending from F_s_c</td>
<td>P = 20.58 kips</td>
</tr>
<tr>
<td>(Max P)/(theoretical P_y)</td>
<td>0.77 (for 8.25&quot; deep slab.)</td>
</tr>
<tr>
<td>Theoretical bending from F_s_c</td>
<td>P = 10.69 kips (for 5.25&quot; deep slab.)</td>
</tr>
<tr>
<td>(Max P)/(theoretical P_y)</td>
<td>1.49 (for 5.25&quot; deep slab.)</td>
</tr>
</tbody>
</table>

The 0.77 and 1.49 bounds on maximum-to-theoretical values indicate that the slab response lies between the values expected for the assumed 8.25" depth and the designed 5.25" depth. The tested strength lies about mid-point between the limits.

In Figure 3 shows comparisons for this slab. The left sloped line is the theoretical elastic load-deflection curve for a slab which is a uniform 8.25" deep over its entire length. The 5.25" marked line represents the linear response expected for a composite slab of uniform depth over its full span.
Load deformation results are shown in Figure 4 where numerical load levels, Y, are shown immediately below the associated grid line. X-axis deflections are marked immediately right of their grid line. The following results obtained where P represents the externally applied load.

- **Maximum external load**: \( P = 15.40 \text{ kips} \)
- **Measured first yield load**: \( P_y = 12.46 \text{ kips (average from both tests)} \)
- **Theoretical bending from \( 0.6F_yS_c \)**: \( P = 12.35 \text{ kips} \)
- **Theoretical bending from \( F_yS_c \)**: \( P = 20.58 \text{ kips} \)
- \( \frac{(\text{Max P})}{(\text{theoretical P})} \) for an 8.25" deep slab: 0.75
- **Theoretical bending from \( F_yS_c \)**: \( P = 10.69 \text{ kips (for 5.25" deep slab)} \)
- \( \frac{(\text{Max P})}{(\text{theoretical P})} \) for a 5.25" deep slab: 1.44

In Figure 4, the measured slab response generally follows that expected for an 8.25" deep slab for the typical working load range. Above this load level, the slab continues to respond as one with a total depth intermediate to the 5.25 and 8.25 inch depths as expected since the deflection is based on an average moment of inertia containing both cracked and uncracked section properties. At low stress levels, the uncracked section modulus should be more dominant. If design values were to be set for \( 0.6F_y \), the upper limit here would be 9.24 kips which is quite near the intersection of the two lines.
The No. 2D slab shows more non-linearity nearing 0.6$F_y$ than does the previous slab. Still, its measured deflection response agrees well with that for the 8.25" slab up to about 0.5$F_y$. Then it drops off but remains well above the 5.25" line to well beyond the measured yield level.

These *damaged* deck slabs exhibited strength and stiffness characteristics well above that expected for the original 5.25" design depth. This is an expected response because the tensile strength of the deck was maintained and the effective depth of the slab had been increased by the induced buckles in the section.

**References**