EVALUATION OF THE PERFORMANCE OF CAZALY HANGERS IN PRESTRESSED CONCRETE JOISTS

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ABSTRACT

Creep, shrinkage and thermal changes create strain in members that can cause serious cracking. The horizontal stress that volume changes create in the member needs to be taken into consideration. Cazaly hangers help to alleviate this stress by allowing lateral movement. The design for this connection, specified by the Precast/Prestress Concrete Institute (PCI) Design Handbook, is conservative and subsequently leads to an impractical and uneconomical design section. The primary objective of this paper is to evaluate the performance of the Cazaly hanger for prestressed concrete joist through full-scale load test. Results show that the failure mode in the prestressed concrete joist with Cazaly hanger is limited by the joist shear capacity and not by the yielding of the Cazaly hanger. To this end, the Cazaly hanger can safely take more loads than the current design specification allows. The code's assumption that the moment carried by the hanger is centered around the middle of the strap where it is welded does not appear to be correct. It is recommended then that design specification for Cazaly hanger in the PCI Design Handbook be modified.

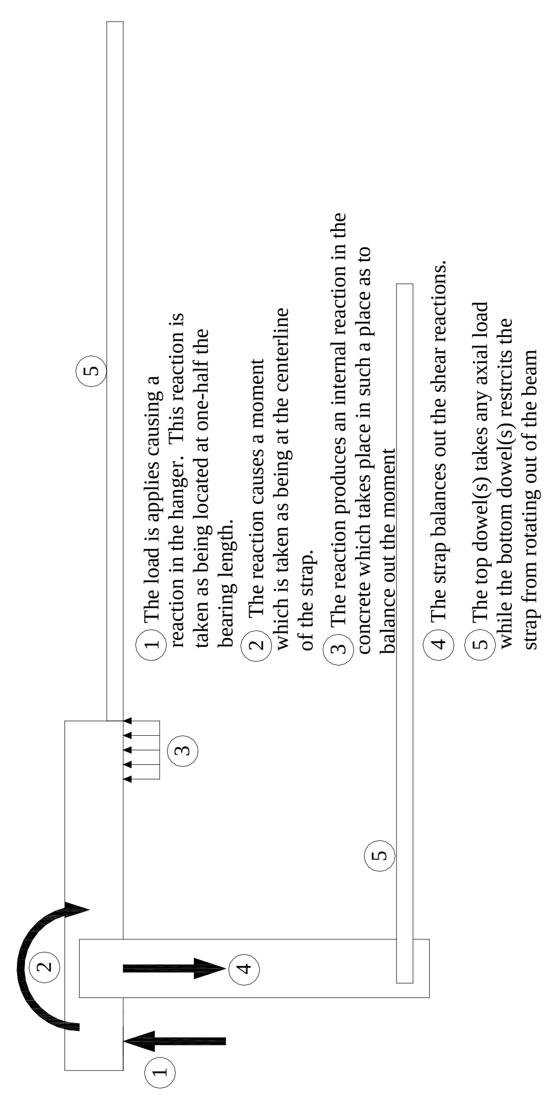
Keywords: Cazaly hanger, Connections, Cracking, Joists, Thermal movement

INTRODUCTION

Hanger connections are commonly used for prestressed concrete joists, where the depth and width of the beam are relatively small. The smaller section of the joist makes it impractical to use dapped ends commonly found in prestressed concrete beams. Hanger connections are very similar to the dapped end connections, but instead of having concrete bearing ends transferring the load, an extended steel bar or tube is used. One typical application of hanger connections is in roof joists in parking garages. These roof systems undergo significant thermal stresses[1], and one method for alleviating the effect of thermal stresses is the use of hanger connection. Volume changes such as creep or shrinkage can cause movement that result in stress buildup in the structural member, which has been shown by many different studies and documents.[2,3,4]

The Precast/Prestressed Concrete Institute (PCI) Design Handbook provides design guidelines for two types of hanger connections, namely the Cazaly and Loov hangers.[5] The Cazaly hanger uses steel strap and cantilever bar to transfer shear forces from the prestressed concrete joist to the supporting beam. In addition, dowels are provided to resist the axial forces and shear friction. Fig. 1 demonstrates the design theory behind the Cazaly hanger. However, there are no moment and shear redistributions, as the PCI assumes that the strap takes all shear forces and that the cantilever arm takes the entire bending moment. This results in an over-simplification of the design approach, which in turn often leads to a very conservative design of steel hangers. These conservative and simplified assumptions for calculating the size of the hangers not only increases the cost of the connection, but also reduce the concrete cover, especially for the joists. Thus, there is a need to re-examine the PCI design guidelines for Cazaly hangers.

These guidelines are based on research on the behavior of Cazaly hangers conducted at the University of Toronto over 40 years ago.[6] Similar research has been conducted more recently at the University of Wyoming,[7] which suggests the need for additional testing. While the two aforementioned studies have provided valuable information on the design of Cazaly hangers, they do not address Cazaly hangers installed on a deeper beam such as prestressed concrete joist, where shear friction and bending capacity are relatively higher. This had formed the motivation for the present study, whereby the governing failure mode of Cazaly hangers in prestressed concrete joists are studied to determine whether current PCI design guidelines are overly conservative.



① The load is applies causing a reaction in the hanger. This reaction is taken as being located at one-half the bearing length.

② The reaction causes a moment which is taken as being at the centerline of the strap.

③ The reaction produces an internal reaction in the concrete which takes place in such a place as to balance out the moment

④ The strap balances out the shear reactions.

⑤ The top dowel(s) takes any axial load while the bottom dowel(s) restrcits the strap from rotating out of the beam

Fig. 1 Cazaly Hanger Design Theory

EXPERIMENTAL STUDY

The main objective of the experimental program is to evaluate the ultimate carrying capacity, in both bending moment and shear, of the hanger installed on a prestressed concrete joist. In addition, the effect of shorter bearing length in the Cazaly hanger is evaluated. The test specimen used was a prestressed concrete joist that was cut into approximately 84 in. segments to evaluate the shear capacity. A slab was cast on top of the joist to create a composite section reflective of actual field conditions, and as well to facilitate the application of the load.

The specimens, as approximately shown in Fig. 2, were loaded with the setup that can be seen in Fig. 3. The specimen was loaded at a rate of about 75 lbs. per second. The loading was paused at different loads to mark cracks and take pictures of the specimen. Once the load reached 100 kips (67 kips reaction) the load was sustained for a 24 hours period. The 24 hours sustained load was to test whether the joist can sustain a load at service level. Once the 24 hour sustained loading period was over, the loading continued to be applied until the specimen failed.

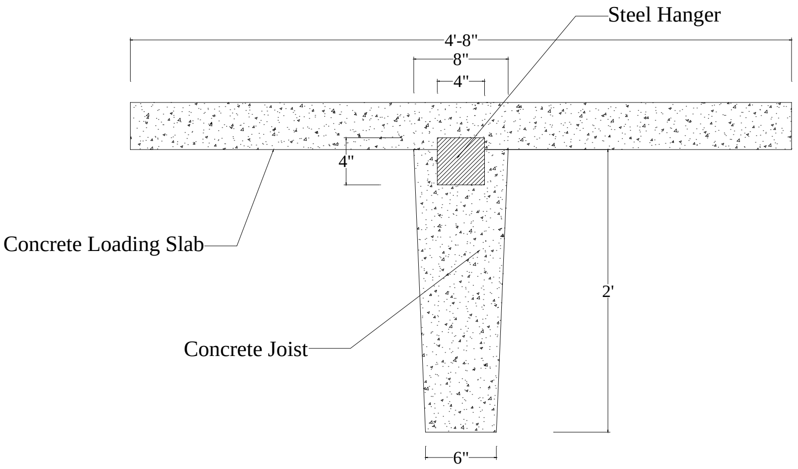


Fig.2 Representative Cazaly Specimen

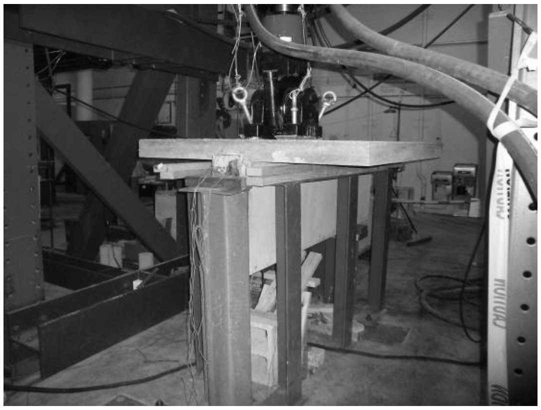


Fig. 3 Test Setup

Of the specimens tested (see Table 1), three hanger specimens, which had a 4 in. x 4 in. cantilevered bar, were tested under regular bearing conditions and three under short bearing conditions. Regular bearing is about 3 in. and short bearing was tested at about 1 in. as is shown in Fig. 4.

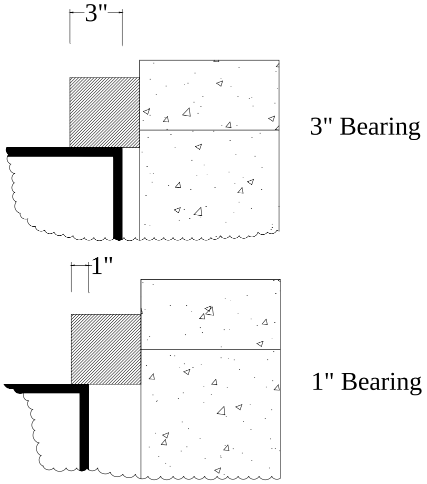


Fig. 4 Bearing Conditions

Table 1: Specimen Description

	Bearing	Cantilevered Bar Dimensions
4 x 4 R-1	3 in.	4 in. x 4 in.
4 x 4 R-2	3 in.	4 in. x 4 in.
4 x 4 R-3	3 in.	4 in. x 4 in.
4 x 4 S-1	1 in.	4 in. x 4 in.
4 x 4 S-2	1 in.	4 in. x 4 in.
4 x 4 S-3	1 in.	4 in. x 4 in.

EXPERIMENTAL RESULTS

From the calculations given in the PCI Design Handbook it can be found that the maximum reaction load for the 4 in. × 4 in. hanger is 69.2 kips as is shown in the calculation below. These values are useful when comparing the actual results to the ones given by the Handbook.

$$A_s = \frac{1.33V_u}{\phi F_y} \rightarrow V_u = \frac{A_s(\phi F_y)}{1.33} = \frac{[(0.375)\times(2\times 4)][(0.90\times 36)]}{1.33} = 73.1 \text{ kips} \quad (1)$$

$$M_{u_{required}} = V_u a = 73.1\times 5 = 366 \text{ kip-in} \quad (2)$$

$$M_{u_{\text{sup} \; plief}} = \phi F_y \frac{bd^2}{6} = 0.90\times 36\times \frac{4\times 4^2}{6} = 345.6 \text{ kip-in} < 366 \text{ kip-in (Moment Controls)}, \quad (3)$$

$$V_u = \frac{346}{5} = 69.2 \text{ kips} \quad (4)$$

The general observations of the tests are as follows. The first cracks were observed in the concrete around the hanger area as shown in Fig. 5. These cracks appeared as early as 16 kips applied load (approximately 10.7 kips reaction load) and as late as 40 kips (approximately 26.7 kips reaction load). These cracks do not really have structural significance in terms of beam failure.

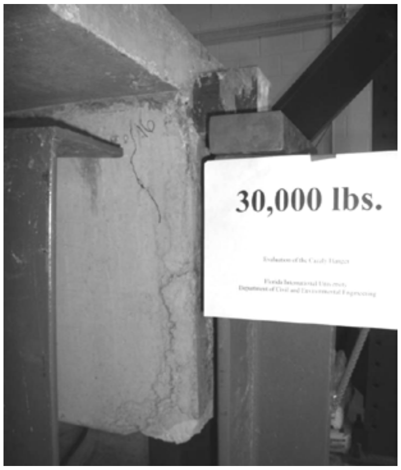


Fig. 5 First Cracks Observed Around the Hanger Area

The second cracking pattern observed of significance was transverse cracking that opened at approximately the same depth as the bottom dowel. These cracks generally occurred at about 60-90 kips (approximately 40-60 kips reaction load). These cracks were significant because they demonstrated that the bottom dowels, whose presence was to keep the hanger from rotating out of the beam, were beginning to fail. An example of these cracks is shown in Fig. 6.

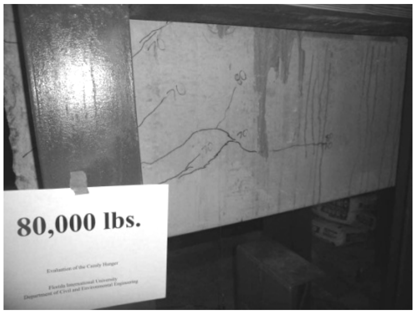


Fig. 6 Transverse Cracking

During the period of sustained load the only cracking was the extending of the transverse cracks as well as the other cracks. Occasionally, additional cracks were observed but since they might have been there previously (i.e. while the load was still being increased) it is difficult to say whether these cracks did indeed open in the sustained load period.

The final failure in most specimens occurred by sudden shear failure of the hanger. This failure occurred generally in the ranger from 140-160 kips applied load (93.3-106.7 kips reaction load). The load was then removed and the test stopped. The maximum loads are summarized in Table 2 as averages of each specimen type and bearing condition. Fig. 7 shows the shear failure of the joist. This is significant because the strap is not designed for bending. After the joist failure, the hanger would punch would through the slab as is shown in Fig. 8.

Fig. 7 Shear Failure of the Beam

Fig. 8 Hanger Punched Through Slab

Table 2: Maximum Loads for Each Specimen

Specimen	Maximum Load (lbs.)	Theoretical Reaction (lbs.)	Maximum Reaction (lbs.)	Percentage
4 x 4 R-1	136,795	69,200	91,197	132 %
4 x 4 R-2	146,098		97,399	141 %
4 x 4 R-3	154,335		102,890	149 %
4 x 4 S-1	153,747		102,498	148 %
4 x 4 S-2	157,790		105,193	152 %
4 x 4 S-3	152,899		101,933	147 %

REGRESSION ANALYSIS

Regression analysis was performed to determine the reason for the reduced moment. Table 3 shows the dimension of the hanger in each test, the distance of the strain gauge from the location of the reaction (as is assumed in the PCI Design Handbook), the bearing condition, and the number of data points for each test (the varying number of data points is due to faster or slower loading and pauses in the loading to mark cracks).

The placement of the strain gauge above is an experimental value to be compared to the value obtained from the regression analysis. If the value found for the moment arm is less than the value above then the moment would be less than the code's.

Table 3: Regression Analysis on Four Specimens

Specimen Number	**Hanger Size**	**Placement of Strain Gauge (in.)**	**Bearing Condition**	**Number of Data Points**
4 x 4-R	4 x 4	2.22	Regular	1878
4 x 4-S	4 x 4	1.5	Short	2809

TEST 4 X 4-R

This section was a 4 in. x 4 in. section therefore the elastic section modulus would be:

$$S = \frac{bd^2}{6} = \frac{4 \times 4^2}{6} = 10.67 in^3 \quad (5)$$

Based upon this and an assumed modulus of elasticity of 29,000,000 psi, the moment can be solved. The reaction is taken to be 2/3 of the applied load. Regression analysis can be used for the 1878 data points. The following equation was found:

$$Moment = y = 0.855x, \text{ where x is the reaction} \quad (6)$$

$$r^2 = 0.9832 \quad (7)$$

The correlation coefficient (r^2) for this analysis as is shown was 0.9832, which demonstrated good correlation between the data points.

TEST 4 X 4-S

This was a short bearing test that had the same section as the previous one as well as the same modulus of elasticity. The equation found for this test along with the correlation coefficient were:

$$Moment = y = 2.0328x, \text{ where x is the reaction} \quad (8)$$

$$r^2 = 0.9873 \quad (9)$$

It is interesting to note that the moment arm is larger as is the initial moment. In the experimental testing the failure load was approximately the same, but the stress was much higher. This is shown by comparing the moment equation above with the similar one for regular bearing. The stress would increase faster for the short bearing test due to a higher moment arm.

Table 4: Specimen with Moment Reduction from the Theoretical Moment Arm to the Calculated Moment Arm

Specimen	**Theoretical Distance from Strain Gauge to Reaction (in.)**	**Calculated Distance from Strain Gauge to Reaction (in.)**	**Percentage of Moment Reduction**
4 x 4-R	2.22	0.855	61 %
4 x 4-S	2.50	2.033	18 %

The results, as summarized in Table 4, show that under normal bearing conditions the moment reduction was greater than in the short bearing condition. This would obviously be due to the fact the moment arm does not have as much space to move towards the face of support. As the loading and consequently moment increase, the deformation increases. This deformation causes the bearing to shorten as the end of the bar loses contact with the support. Under regular bearing conditions, this bearing decrease is more pronounced and has a greater effect on the decrease in the moment. The shorter bearing is not as great to begin with and therefore the reduction is not as noticeable.

CONCLUSION AND FUTURE RESEARCH

The test showed that the Cazaly hanger design given in the PCI Design Handbook was over-simplified resulting in a conservative design. It was shown that the short-bearing condition needed special commentary since the stress was higher for this condition, but could carry sufficient load. The observations demonstrated that the strap, which is not at present designed for bending, seemed to undergo bending which may limit the hanger's capacity.

The conclusions that have been reached can be summarized into three main points:

1) The hanger can safely take more load then the Handbook allows.
2) Shorter bearing length increases the deformation and corresponding strain. A check should be placed upon short bearing conditions for construction purposes.
3) The Handbook's assumption that the moment carried by the hanger is centered at the middle of the strap where it is welded does not appear to be correct.

4) The distance, given as an assumption in the Handbook that the makes the internal reaction $0.33V_u$, need not be there if the strap is proportioned correctly.

Future research study should include the behavior of the strap as it would indicate how the load is transferred as the bar interacts with the concrete and the strap. It is possible that the shear force reacts differently from the Handbook and therefore it is important to find the location of maximum moment. Currently the Handbook takes this maximum moment to be at the center of the strap, but if the bar acts more like a fixed end (with the fixed end being at the face of the concrete) this would further decrease the moment, possibly even more than has been shown here.

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