



Project Summary Report O-2102-S

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Project O-2102: Study of Dapped Girder Ends on Steel Structures

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## Evaluation of Dapped Girder End Details on Steel Highway Bridges

Bridges in Texas often incorporate long steel girder spans immediately adjacent to shorter, prestressed concrete girder spans. In such cases, when the steel and concrete girders meet end to end over a common support (a bent), the two members are usually different depths (Figure 1). This geometric problem is commonly resolved in one of two ways:

- A step is sometimes placed in the bent cap to accept the shallow concrete girder on one side and the deep steel girder on the other (Figure 1a).
  - The deep steel girder can be made shallower at its terminal end, or dapped, to rest at the proper elevation on a flat bent cap end to end with the concrete girder (Figure 1b).
- Three different dapped details used in Texas



Figure 1. (a) Stepped Bent Cap. (b) Dapped Girder.

(Figure 2) were evaluated in this project:

- a notched detail,
- a 90-degree rounded detail, and
- a tapered detail.

Currently, design standards for dapped end details do not exist. Consequently engineers have employed many variations of dapped details. Some of the variations involve complicated arrangements of stiffener plates and welds and an associated high cost of fabrication.

Additionally, in some cases dapped details have developed severe problems with fatigue cracking. For example, since the early 1960s, dapped steel girders

have been used in Japan, the most common application being the 90-degree rounded detail. Since the mid-1970s, hundreds of instances of fatigue cracking have occurred in Japan involving this detail.

### What We Did...

The objective of this project was to provide a technical basis for the standardized design of dapped girder ends on steel highway bridges. The research team designed analytical and experimental investigations to provide information about the fatigue behavior and the ultimate strength behavior of dapped steel girders.



## Case Study Bridge and Dapped Girder End Details

Researchers based the dapped girder end details investigated in this project, both as test specimens and as analytical models, upon actual designs in service in Texas. The Texas Department of Transportation (TxDOT) Houston District Office provided detailed drawings of a bridge in Montgomery County on IH-45. For the purposes of this project, the bridge was considered representative of bridges employing dapped details. Each of the three details from Figure 2 was studied in turn as though it constituted the dapped girder ends of the case-study bridge.

### Fatigue Behavior

Because the dapped region of the girders is subjected to a variable-amplitude, multi-axial stress history, the investigation required a special effort to examine the fatigue behavior of the dapped details analytically under service-load conditions. Three-dimensional finite element models were assembled for the entire case-study bridge. In addition to the global models, local refined submodels of the dapped regions were constructed using solid elements. The results of these procedures helped researchers establish and compare the fatigue strength among the three details.

### Ultimate Strength Behavior

The examination of the ultimate strength behavior

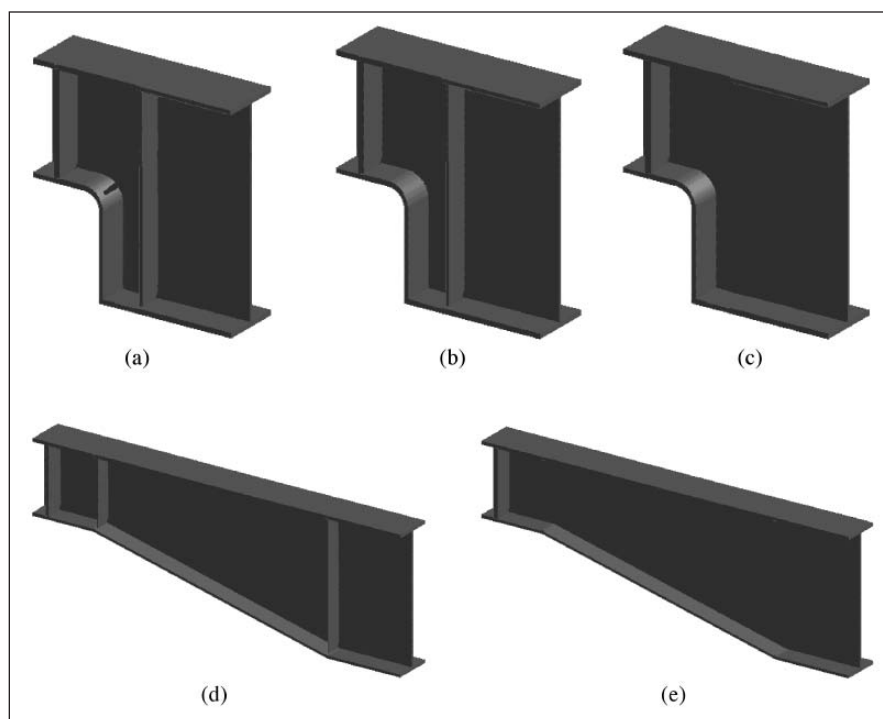


Figure 2. Bent-Plate, Welded-Flange, Dapped Girder End Details Considered in Project 0-2102.

of dapped girder ends used a series of three-dimensional finite element models. Based upon the results from the initial set of analytical models, three specimens for laboratory testing were designed. These test specimens were modeled analytically in a similar fashion so that the analytical predictions could be compared with experimental results. The goal of the tests was to examine nominal shear force resistance and specifically the post-buckling behavior of test panels that incorporate dapped details.

### What We Found...

#### Fatigue Considerations

Among the three dapped details considered in this project, notched details possessed the lowest fatigue strength.

Two zones of local stress concentration were observed: at the reentrant corner of the notch and in the web plate at the end of the extended horizontal flange plate.

The 90-degree rounded details possess an intermediate fatigue strength when compared to notched details and tapered details. Two zones of local tensile stress concentration were observed. Both zones are located in the web plate where it joins the curved flange plate. One zone is located between the apex of the bend and the horizontal tangent point. The other zone is located between the apex of the bend and the vertical tangent point.

The tapered details possess the highest fatigue strength. Two zones of local tensile stress



concentration were observed. One zone is located in the web plate at the apex of the bend nearer to the support. The other zone is located in the flange plate at the apex of the bend that is farther from the support.

### **Ultimate Strength Considerations**

Each of the dapped girder end details considered in this project developed a full tension field following shear buckling of the web plate. This included cases in which the tension field occurred within the end panel and cases in which the end panel was tapered. The ability of a dapped detail to anchor an end-panel tension field is attributable to the increased compactness of the web plate in the vicinity of the support.

The ultimate strength behavior of girders that incorporate a 90-degree rounded detail is the same as that of otherwise identical girders that incorporate a 4:1 tapered detail. Hence, special intermediate stiffeners installed at flange bend locations in tapered details may not be necessary. When calculating the shear capacity of a tapered panel, it is conservative to assume the panel is of a uniform depth that is equal to the maximum depth of the panel. (Of course, the full plastic capacity at the terminal end of the panel must also be checked.) Therefore, when a dapped detail is used, it may be possible to eliminate one or more sets of intermediate transverse stiffeners near the end of the girder.

## **The Researchers Recommend...**

### **Notched Detail**

Researchers do not recommend continued use of the notched dapped girder end detail in any of its forms. Existing notched girder end details should be monitored at abbreviated inspection intervals to ensure that fatigue cracks, should they form, are detected early. Particular attention should be given to the web plate at two locations: the reentrant corner at the notch and the end(s) of any welded longitudinal plates that extend away from the notch.

### **90-Degree Rounded Detail**

Researchers recommend monitoring existing 90-degree rounded dapped girder end details at regular inspection intervals to ensure that fatigue cracks, should they form, are detected early. Particular attention should be given to the fillet welds connecting the web plate to the flange plate in the vicinity of the apex of the bent flange plate. In addition, the ends of any welded longitudinal plates that extend from the apex of the bent flange should be given attention.

To avoid failures at the root of the fillet weld in the critical zone, designers should consider using a complete joint penetration (CJP) weld to join the web plate to the bent portion of the flange plate. It is

important to note, however, that not all of the fatigue cracks in this detail in Japan have been root failures. A number of toe failures have also occurred, which is a failure of the web plate itself. Use of the CJP weld will improve the situation for the web plate, but a program of fatigue testing would be needed to determine a definitive solution.

### **Tapered Detail**

Researchers recommend monitoring existing tapered dapped girder end details at regular inspection intervals to ensure that fatigue cracks, should they form, are detected early. Particular attention should be given to the fillet welds connecting the web plate to the flange plate in the vicinity of the apex of the bent flange plate nearer the support. Particular attention should also be given to the welds connecting any transverse stiffeners to the tension flange in the vicinity of the apex of the bent flange plate farther from the support.

The stress concentration in the web plate at the bend nearer to the support is not as severe as in the 90-degree rounded detail, but a similar zone of elevated stress is present there. Potential problems with fit-up in the shop also exist. Designers should consider using a CJP weld to join the web plate to the bent portion of the flange plate, especially for steep tapers.



## For More Details...

The research is documented in:

Report 0-2102-1, *Behavior and Design of Dapped Steel Plate Girders*

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## TxDOT Implementation Status—April 2005

It is necessary to notch or dap steel girders to transition from steel bridge superstructures to concrete superstructures. There are many variations of the dapped end detail, which leads to fabrication problems and inefficiencies. It is now known that the most efficient detail combines a bent plate with a welded splice at the bottom flange, but the exact requirements for weld type, strength, and acceptance are not known. Additionally, web stiffener details in the dapped end region vary from project to project. Research project 0-2102, "Study of Dapped Girder Ends on Steel Structures," has provided a theoretical basis for detailing dapped steel girder ends. Discussions will be held with the researcher, TxDOT bridge engineers, and steel girder fabricators to develop a consensus for standardized details and inspection and testing requirements. A formal implementation project is being considered for development of such standards.

For more information, contact Tom Yarbrough, Research and Technology Implementation Office, at (512) 465-7403 or e-mail tyarbro@dot.state.tx.us.

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