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Parametric Analysis and Ultimate Testing of Bascule Trunnion Assemblies

Thomas A. Cherukara
Florida Department of Transportation
&
Glen Besterfield and Autar Kaw
University of South Florida

ADAMS MARK RESORT
DAYTONA BEACH, FLORIDA

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Thomas A. Cherukara
Florida Department of Transportation
thomas.cherukara@dot.state.fl.us

Glen H. Besterfield
University of South Florida
besterfi@eng.usf.edu

Autar K. Kaw
University of South Florida
kaw@eng.usf.edu

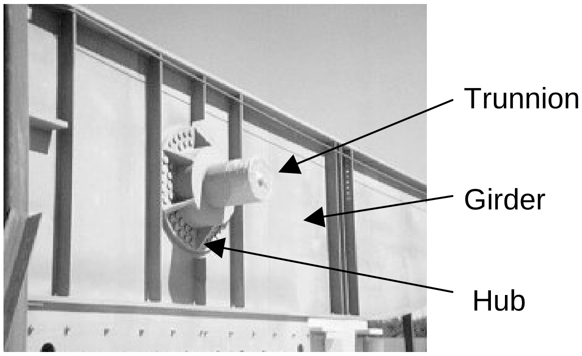
ABSTRACT

The paper presents an overview of the research on trunnion-hub-girder (THG) assemblies for bascule bridges conducted at the University of South Florida for the Florida Department of Transportation. A parametric model of the assembly was developed and temperatures, hoop stresses, Von-Mises stresses and critical crack lengths for the trunnion-hub-girder assembly were analyzed through the assembly process for transient and steady state conditions. The finite element analysis was followed by a full-scale ultimate testing of an assembly. This provided a comprehensive study and quantitative analysis of the thermo-mechanical behavior of the components and the system. The experimental observations of temperatures and stresses for transient and steady states closely matched the theoretical analyses.

The factor of safety for shrink-fitting the trunnion into the hub and the hub-trunnion into the girder utilizing liquid nitrogen cooling was doubled by first shrink-fitting hub into girder followed by trunnion into the hub-girder assembly. Cooling of the inner component in dry ice and alcohol and heating the outer component could easily avoid the undue risks associated with both these procedures. The heating of the outer component of the shrink fit assembly has significant advantages over the sub-cooling of the inner component. The parametric modeling identifies the maximum stress conditions for each procedure and analyzes the risks and economics of the assembly alternatives. Technical background on the assembly options is illustrated, along with the detailing aspects vital to the fabrication of the components and their assembly. The findings benefit engineers and contractors in designing and analyzing trunnion assemblies for bascule projects.

INTRODUCTION

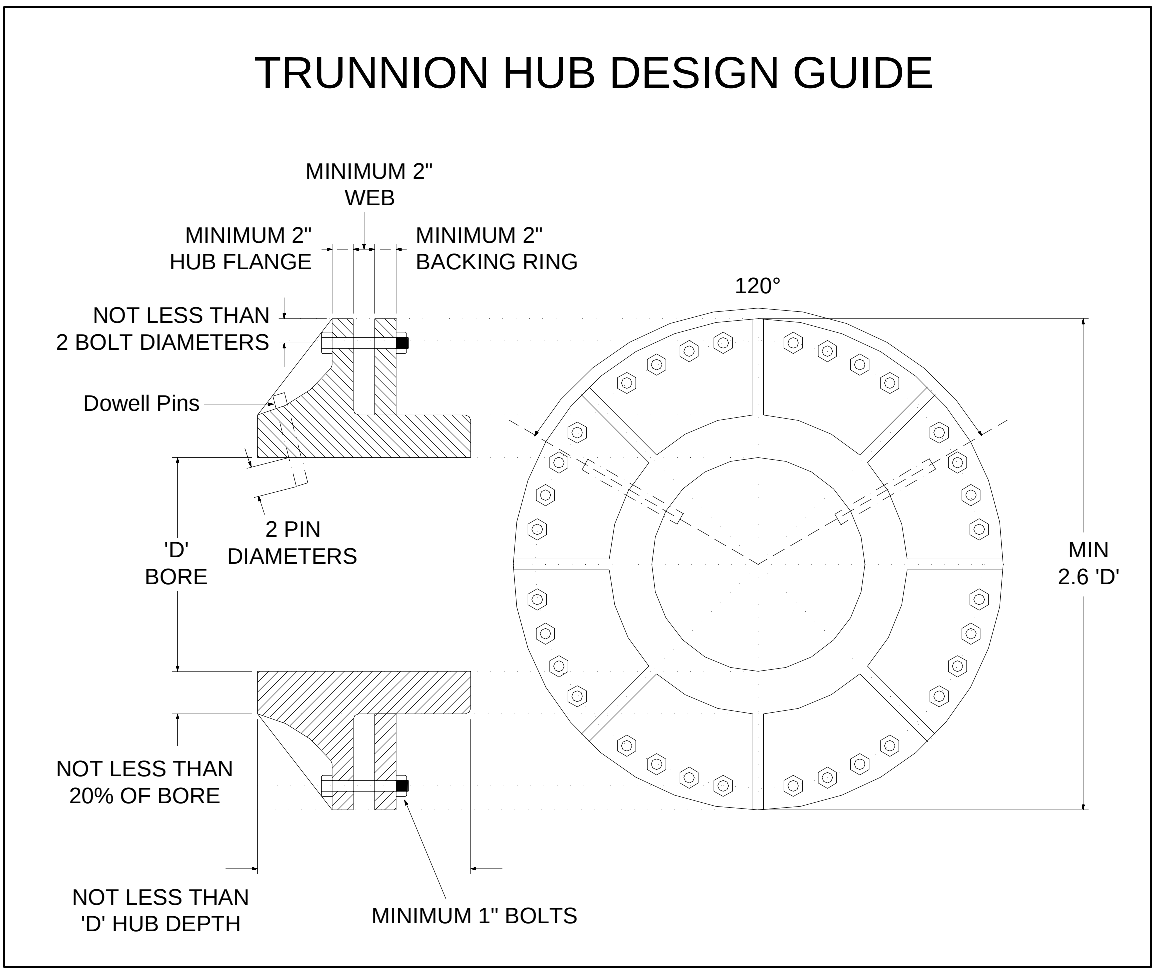
The ‘Bascule’ is the French word for “seesaw.” It belongs to the first class of levers, where the fulcrum is located between the effort and the resistance. However, the bascule bridge belongs to the second or third class of levers depending on how the load is designated. Zooming in on the fulcrum of the bascule, the leaf seems to pivot on a fixed axis. The pivot assembly consists of a trunnion shaft attached to the leaf girder via a hub, and supported on bearings to permit rotation of the leaf. The Trunnion-Hub-Girder assembly forms the pivotal element of the bascule mechanism (Figure 1).



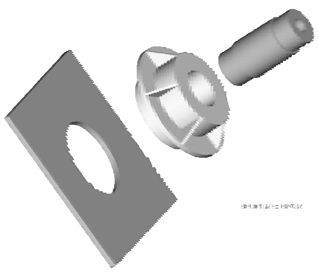
Assemblies of this type are generally constructed with interference fits between the trunnion and the hub, and between the hub and the girder. The interference fits allow the trunnion to form a rigid assembly with the leaf and permits the rotation of leaf through bearings. The two interference fits are supplemented by keys or dowel pins at the trunnion and by structural bolts at the girder. The recommended detail for hubs is shown in FDOT LRFD Design Guidelines 2002 (Figure 2).

Figure 1. Trunnion-Hib-Girder assembly

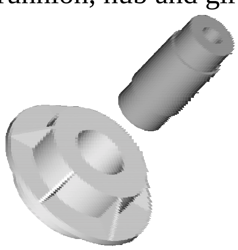
Figure 2. Hub Detail (FDOT LRFD Design Guidelines 2002)



Basically two procedures are utilized in accomplishing the THG assembly. They are illustrated in sequential assembling order in Figure 3 and Figure 4. Assembly Procedure (AP) 1 involves cooling the trunnion and shrink-fitting it into the hub, and then cooling the trunnion-hub assembly to shrink-fit it into the girder. Assembly Procedure (AP) 2 involves shrink-fitting the hub into the girder, then cooling the trunnion and shrink-fitting it into the hub-girder assembly. Each procedure has its own limitations and merits. The FDOT commissioned a research project at the University of South Florida to study the transient and steady state thermo-mechanical behavior of the assemblies during the two procedures and to optimize the design and construction. The results of the finite element analysis of the assembly along with the full-scale tests are presented. Also FDOT experience over the years in the design and construction of THG assemblies are evaluated in light of the research findings, and several recommendations critical to the design, detailing, specification and construction of THG assemblies are presented under conclusions.



Trunnion, hub and girder



Trunnion fitted into hub