



## Assessment of End Zone Cracking in Precast Prestressed NU Girders in Bridges

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## Summary

NU girders, a type of precast prestressed concrete girder with I-shaped cross-section, have been widely used as bridge girders in Alberta, Canada, since 2001. Cracks in the end zones after fabrication are usually between 0.1 mm to 0.5 mm wide and may pose a risk to serviceability, durability and/or load carrying capacity of the girders. Condition inspection guidelines for bridges led to very low ratings (i.e. girder rated as poor) of new girders due to these end zone cracks.

The objectives of this study were to assess the amount and pattern of end zone cracking through inspections of selected in-service NU girder bridges, to analytically and numerically assess potential risks of cracks and to develop guidelines for condition inspection for these girders. The inspection program included detailed visual inspections of the end zones of 21 bridges with various NU girder simple span and continuous bridge configurations. Analyses were carried out to evaluate the impact of cracks on the shear capacity in the girder end zones and in the bearing zones with respect to serviceability and structural safety such as end zone bearing and shear. Crack widths were also evaluated with respect to durability.

The results show that most cracks in the girder end zones likely formed during fabrication and construction. The cracks typically remain hairline (0,1 mm or less) under service conditions and do not pose safety concerns. Narrow cracks (0,2 mm to 0,5 mm) usually do not reduce the load carrying capacity and serviceability of the girders, but could affect long-term durability. Condition inspection guidelines were proposed for adoption to NU girders. These included guidelines to identify cracks that have the potential to affect the load carrying capacity of the girders.

**Keywords:** bridges, girders, prestressing, cracking, end zones, inspection, analysis.

## 1. Introduction

NU girders are a relatively new type of prestressed concrete girders that have been used as bridge girders in Alberta, Canada since 2001. NU girders are precast/prestressed concrete girders with optimized cross sections for the use of higher strength concrete. Many existing NU girders have cracks up to 0,5 mm in width in the girder end zones, which has led these girders to be rated as being in "poor condition". These low inspection ratings led to concern by the Ministry of Transportation in Alberta, and a study was carried out on 21 bridges to determine the risk of end zone cracking to the structural integrity and durability of the girder end zones as well as to update the condition inspection guidelines for NU girders in Alberta. The paper focuses on the 12 structures without draped prestressing strands.

The study consisted of detailed inspections and analyses of the end zone cracking of NU girders. Possible causes for the end zone cracks were determined from a literature review and using finite element modeling of the prestressing effects on the girder end zones. Recommendations were given on the risk of the observed end zone cracks and whether the cracks should be monitored or repaired. Finally, recommendations for inspection rating guidelines and were developed for different NU girder end zone cracks.

## **2. End Zone Failure Mechanisms**

Failure in the end zone of prestressed girders with thin webs and flanges likely occurs by formation of a fairly wide or several narrow shear cracks in the web, a shear/bond failure caused by slipping of the bottom prestressing strands, and/or local concrete crushing at the bottom of the girder web. Certain cracks in the end zones of NU girders could have the potential to develop into cracks affecting the structural integrity of the girder. These potentially harmful cracks are diagonal cracks in the girder end zones, which could develop into shear zones, vertical cracks in the bottom flanges in the end zones, indicating insufficient prestressing strand anchorage or any cracks in the bearing zone. Any cracks that are collinear with the prestressing strands potentially reduce the bond between the prestressing strands and the concrete girder and may lead to strand slippage and reduce the force transfer at the girder ends through the strands.

## **3. Inspection Results and Condition Inspection Guidelines**

Typical cracks observed during the inspections were radial cracks at the bottom portion of the web just inside the bottom flange radius and horizontal and radial web cracks, bottom flange cracks, and cracking in the web along the post-tensioning ducts. Some of the structures also had other cracks such as cracks at steel diaphragm connection points or lifting hooks, cracks at the top flange or vertical cracks adjacent to cast-in-place concrete diaphragms. The inspection results showed that even though NU girders typically have cracks in the end zone, the majority of the cracks in the NU girders are of a width smaller than 0,3 mm. They do not impact the structural integrity of the girders, and no remedial action is typically required.

Condition inspection guidelines were developed for field inspectors to recognize typical end zone cracks, which do not have an influence on the durability and load carrying capacity and cracks that can potentially affect the load carrying capacity or durability of the girders such as wide cracks, cracks in the bearing zones and cracks that can develop into shear cracks

## **4. Conclusions**

1. Prestressed precast NU girders typically have cracks in the end zones that form during fabrication. Typical cracks are radial and horizontal cracks in the web and in the bottom flange due to tensile forces between groups of prestressing strands as well as cracks along post-tensioning ducts. Most cracks remain within a width of 0,1 mm or less and should not present a danger to the girders.
2. Cracks with widths between 0,1 and 1,0 mm usually do not reduce the load carrying capacity and serviceability of the girders, but could affect long-term durability, and filling of the cracks, e.g. with epoxy injection, may be required.
3. Some cracks have the potential to develop into shear cracks or are in the bearing zone and may affect the load carrying capacity of the girders. These cracks usually require further assessment.
4. Condition inspection guidelines were proposed for NU girders to differentiate between cracks that are not expected to affect the girder performance and cracks that have the potential to reduce the load carrying capacity or durability of the NU girders.