Thin-Walled Structures 52 (2012) 158–164

Contents lists available at SciVerse ScienceDirect

Thin-Walled Structures

journal homepage: www.elsevier.com/locate/tws

Interaction of multiple piping penetrations used in mining and petrochemical facilities

Osama Bedair

OB Engineering Ltd., 151 Chapalina Mews SE, Calgary, Alberta, Canada

ARTICLE INFO

Article history:
Received 18 September 2011
Received in revised form
11 November 2011
Accepted 12 November 2011
Available online 18 January 2012

Keywords:
Plate girders
Stiffened plates
Oil and gas facilities
Piping stress
Petrochemical facilities
Steel perforations
Structural openings
Finite element

ABSTRACT

The paper presents numerical procedure for stress analysis of structural components surrounding piping penetrations used in oil and gas facilities. The stress components due to the web penetration are determined by introducing fictitious models with assumed normal and tangential force distributions. The magnitudes of these forces are determined by solving set of linear equations. The influence of the perforation eccentricity and spacing on the behaviour of the structure is highlighted for several opening configurations. The influence of the penetration spacing in the vertical and horizontal directions is also investigated. It is shown that the location of the maximum stress is also affected by the penetration spacing. Recommendations are proposed to optimize the pipe penetration spacing for various configurations. It is shown that more than 60% reduction in the web stress can be achieved.

© 2011 Elsevier Ltd. All rights reserved.

1. Introduction

Holes and cut-outs of various shapes are used in practice to allow the passage of services such as pipelines, electrical/instrumentation cables, HVAC ducts, etc. In some cases it is very expensive to route these services around structural members. As a result, it is inevitable to penetrate through structural steel members. Perforated steel girders are encountered very often in mining facilities, offshore platforms, and petrochemical refineries. Fig. 1, for example, shows a three dimensional model for a process facility used in mining operations with multiple pipe penetrations. The intention is to illustrate the amount of piping penetrations encountered during the design phase of these industrial buildings. The presence of these penetrations creates structural interferences that impact the design of the facility. Enlarged detail is also shown in Fig. 1 of typical pipe penetration in the web of W-section. The shown facility contains two major steel buildings that are supported by a common plate girder framing. Due to piping and mechanical requirements the steel structure is elevated 1.5 m above grade. As a result, process pipelines that tie into the main gathering lines are designed to penetrate through the plate girder supports from both sides, as highlighted by the dashed circles in Fig. 1. During operation, plate girders are subject to varieties of loading that includes compression, tensile, shear and bending. The direction and the intensity of these loads change during the start up and shut down. During the FEED (Front End Engineering) design phase, piping and structural engineering teams must coordinate the location of these penetrations within the structure. It is unfortunate that little design guidelines are available in practice for the engineers that may result in drastic mistakes.

Fig. 2 shows another example of perforated plate girder used to support a crusher facility in mining operations. Each support is elevated 3.2 m above grade to facilitate access for installation of mechanical and electrical services. The weight of the facility is approximately 2,600 tons. Structural openings in the apron feeders are highlighted by the dashed lines. Other example of pipe penetrations is shown in Fig. 3.

The presence of openings causes significant stress re-distribution and may introduce local damage in the form of cracks to the structural member at the early stage of operation. Inspection programs are usually conducted on regular basis during shutdown periods to monitor local failures and damages that might occur during operation. However, replacement or repair of the damaged webs is very expensive due to the long periods of operation shut down required. This may result in large financial losses that exceed billions of dollars. Therefore, it is very important to evaluate carefully the influence of structural penetrations during the design phase. Majority of existing design rules are empirical and are valid for specific cases. It is well known that there are several parameters that affect the global or local

E-mail address: obedair@gmail.com

0263-8231/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.tws.2011.11.005

Nomenclature

A^{ij}	Matrix of influence coefficients,
C	External surface of the penetration
D	Diameter of the circular penetration
E	Elastic modulus
f_y	Yield stress
Q^j	Vector of fictitious forces.
q_i	Assumed normal and shear forces,
FM	Fictitious model,
$G_{i,k}$	Influence coefficient matrix;
R	Radius of the curvature;
$S_{ij,k}$, $B_{i,k}$	Stress and the displacement components,
$\sigma_{ji}(x)$	Stress components
$n_j(x)$	Direction of normal,
X^i	Vector of tractions or displacements boundary conditions,
v	Poisson's ratio
$(\sigma^w)_{max}$	Maximum web stress, and

performance of perforated steel members, such as the shape, size, orientation and position of the openings within the webs. It is impossible to combine the effect of all these parameters into simple design guidelines. Although the influence of the web perforations might be localised, they weaken the overall structural capacity. Also it must be highlighted that the location of these penetrations largely influences the design of the structure.

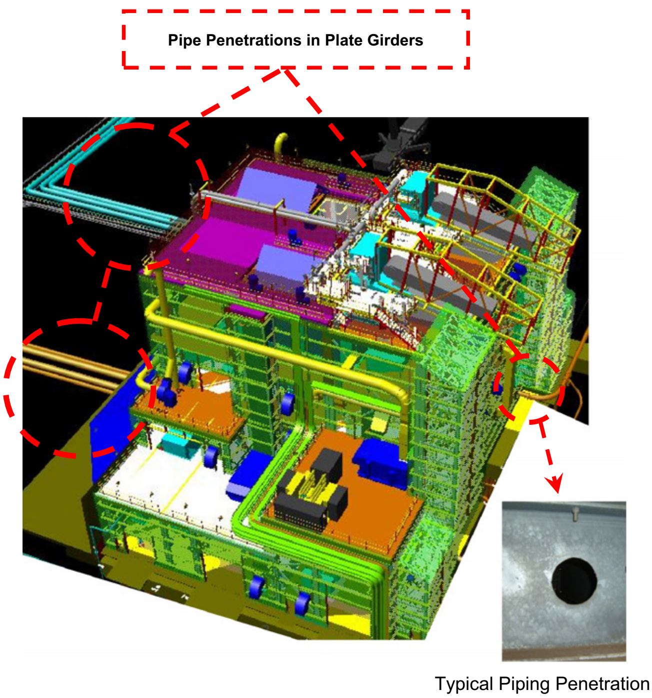

Fig. 1. Three dimensional model of a process facility.

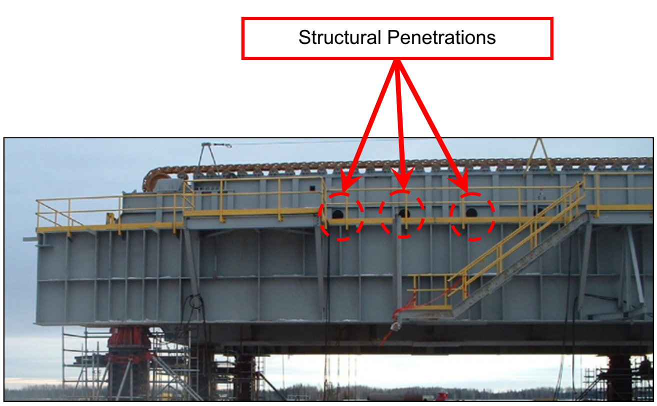

Fig. 2. Elevated plate girder supports.

In some cases, the free edge of the pipe penetrations are reinforced around the perimeter by welding circular rings. However this procedure may result in a very expensive fabrication cost. Alternatively, the opening may be reinforced using steel doublers as shown in Fig. 4. In this case, the thickness of the web is increased due to the addition of the doublers (at both sides) and consequently reduces the stresses in the vicinity of the opening dramatically. Few guidelines are, however, available in practice to select the optimum size of the steel doublers.

Several studies were presented in the past to investigate the behaviour of webs with perforations with application to bridge construction. Limited literature addressed the structural behaviour with application to mining or petrochemical facilities. Shanmugam et al. [1,2] studied numerically buckling behaviour of axially compressed plates. Narayanan and Chow [3], and Narayanan and Darwish [4], studied the behaviour of plate girders with eccentric hole. Komur and Sonmez [5] studied the elastic

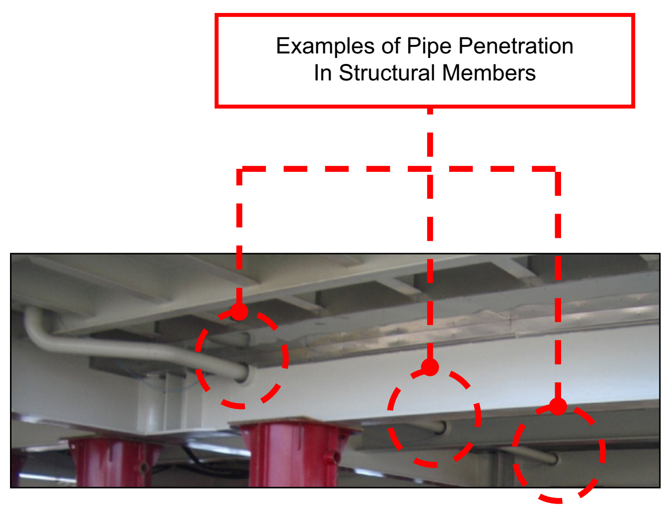

Fig. 3. Example of pipe penetrations.

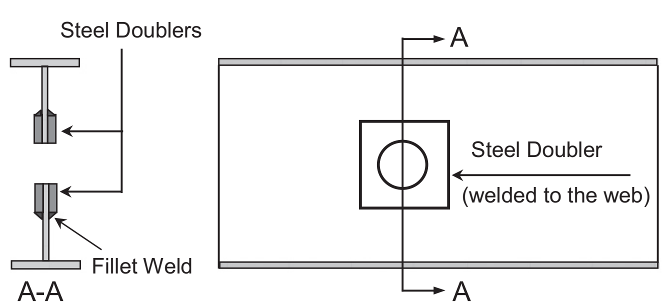

Fig. 4. Steel doublers surrounding the web perforation.

Download English Version:

https://daneshyari.com/en/article/309434

Download Persian Version:

https://daneshyari.com/article/309434

Daneshyari.com