Conception & Consulting Engineering Solutions

Rigidity of Diaphragms

Mixte 2I

CCES

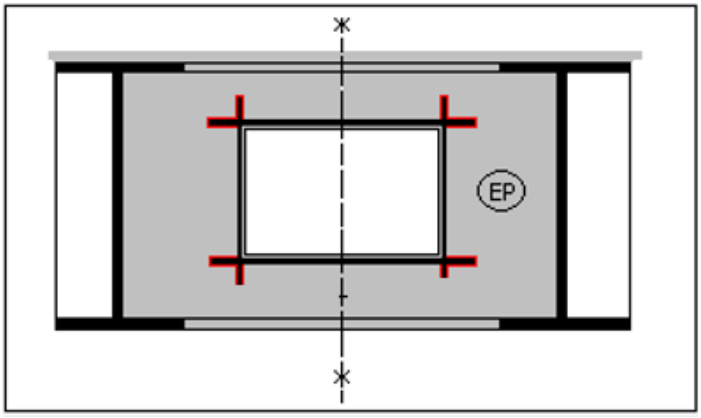
11/11//2024

1 Calculation modes – section characteristics

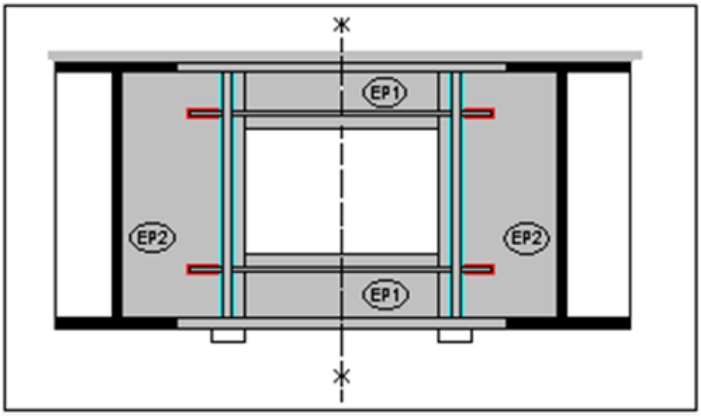
1.1 Introduction

We distinguished two cases according to the type of jacking, under beams and under diaphragm. In the first case, there are the stiffeners of the manhole, two horizontal and two verticals. The thickness of the diaphragm is uniform, equal to EP. In the second case, there are two horizontal stiffeners and the two uprights of the jacking. There are two sheets, the central one with thickness EP1 and the lateral one with thickness EP2 (see figure below).

Jacking under beams



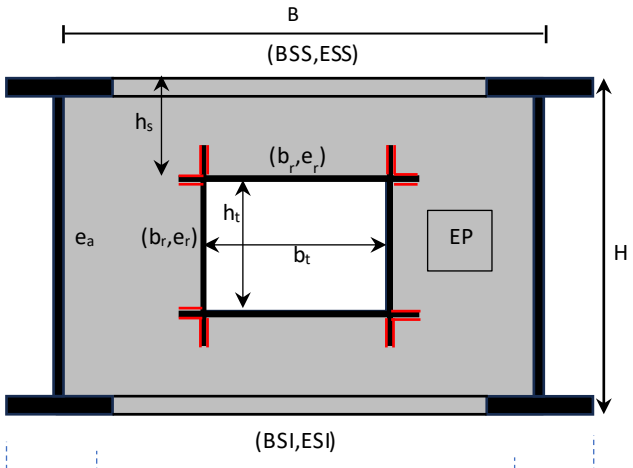
Jacking under diaphragm



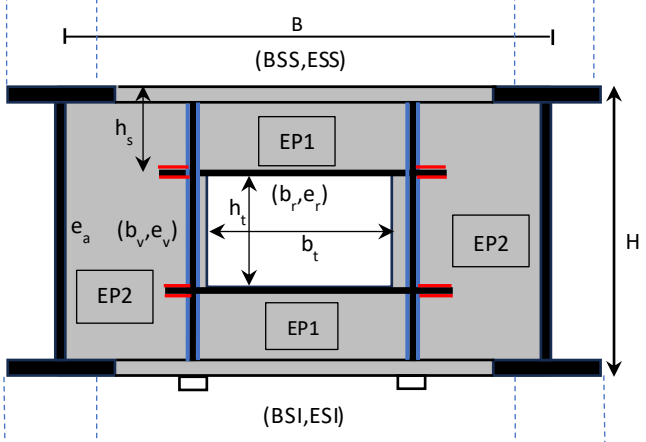
1.2 Calculation model

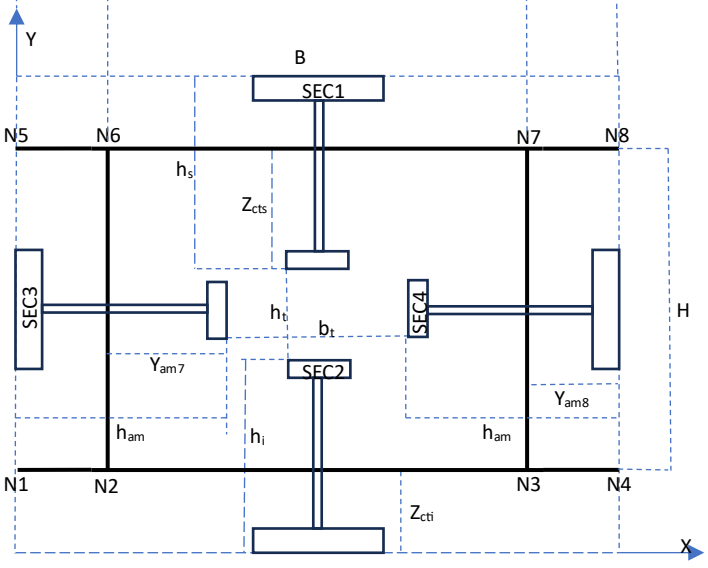
To simplify the problem, we use the following model for the diaphragms:

Jacking under beams



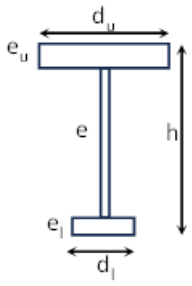
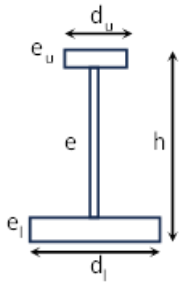
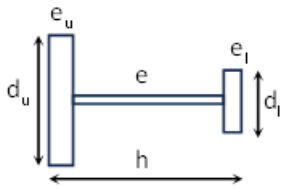
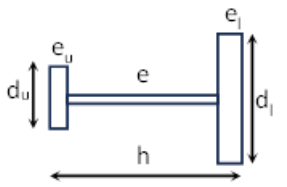
Jacking under diaphragm





1.3 Sections characteristics

The characteristics of the sections shown in the figure above are given in the following table:

Section	Type	d_u	e_u	d_l	e_l	h	e
SEC1		**BSS** **=500mm**	**ESS** Thickness of the upper flange of the main beams	**br** (Jacking under beams) **2*br+EP1** (Jacking under diaphragm) **br** Stiffener width **EP1** Thickness of the central sheet	**er** Stiffener thickness	**hs** Distance from top horizontal stiffener to upper fiber	**EP** Diaphragm thickness (Jacking under beams) **EP1** Thickness of the central sheet (Jacking under diaphragm)
SEC2		**br** (Jacking under beams) **2*br+EP1** (Jacking under diaphragm) **br** Stiffener width **EP1** Thickness of the central sheet	**er** Stiffener thickness	**BSI** **=500mm**	**ESI** Thickness of the lower flange of the main beams	**H-hs-ht** Distance from bottom horizontal stiffener to lower fiber **H** Height of main beams **ht** Height of manhole	**EP** Diaphragm thickness (Jacking under beams) **EP1** Thickness of the central sheet (Jacking under diaphragm)
SEC3		**30ea** **ea** Web thickness of main beams	**ea** Web thickness of main beams	**br** (Jacking under beams) **2*bv+EP2** (Jacking under diaphragm) **br** Stiffener width **bv** Width of jacking uprights	**er** (Jacking under beams) **ev** (Jacking under diaphragm) **er** Stiffener thickness **ev** Thickness of jacking uprights	**Ham** **=(B-bt)/2** **B** Distance of main beams **bt** Width of manhole	**EP** Diaphragm thickness (Jacking under beams) **EP2** Thickness of the vertical sheets (Jacking under diaphragm)
SEC4		**br** (Jacking under beams) **2*bv+EP2** (Jacking under diaphragm) **br** Stiffener width **bv** Width of jacking uprights	**er** (Ver. Sous poutres) **ev** (Jacking under diaphragm) **er** Stiffener thickness **ev** Thickness of jacking uprights	**30ea** **ea** Web thickness of main beams	**ea** Web thickness of main beams	**Ham** **=(B-bt)/2** **B** Distance of main beams **bt** Width of manhole	**EP** Diaphragm thickness (Jacking under beams) **EP2** Thickness of the vertical sheets (Jacking under diaphragm)

1.4 Node coordinates

Noeuds	X	Y
N1	0	Z_{cti}
N2	h_{am}- Y_{am7} with $h_{am}=(B-b_t)/2$	Z_{cti}
N3	B-Y_{am8}	Z_{cti}
N4	B	Z_{cti}
N5	0	H-(h_s-Z_{cts})
N6	h_{am}- Y_{am7} with $h_{am}=(B-b_t)/2$	H-(hs-Z_{cts})
N7	B-Y_{am8}	H-(h_s-Z_{cts})
N8	B	H-(hs-Z_{cts})

Respecting the characteristics of the sections, for the simplified model, we calculate the coordinates of the nodes of the model:

The nodes and the different variables are displayed in the previous figure.

The variables Yindice and Zindice are the distances of the center of gravity of the sections of the outer fiber of the lower flange of the section:

Section	Distance center of gravity-lower flange
SEC1	Z_{cti}
SEC2	Z_{cts}
SEC3	Y_{am7}
SEC4	Y_{am8}

1.5 Definition of members

We consider the members N1-N2, N3-N4, N5-N6, N7-N8, N2-N3, N6- N7, N2-N6, N3-N7 without divisions.

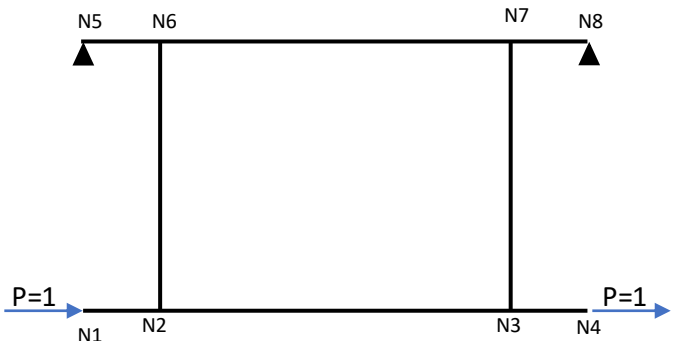
Elements	Section
N1-N2	Rigid
N2-N3	SEC2
N3-N4	Rigid
N5-N6	Rigid
N6-N7	SEC1
N7-N8	Rigid
N2-N6	SEC3
N3-N7	SEC4

1.6 Support conditions

The supports are located at nodes N5 and N8 with the X and Y displacements blocked.

1.7 Stiffness of the springs at the lower flange of the main beams

We apply two unit-forces in the same direction, one at node N1, the other at node N4.
The program calculates the deformation. Let f be the maximum transverse displacement.
The rigidity of the frame is therefore equal to: $C_d = 1/f$



This calculation is made for all positions of diaphragms. The SEC1 and SEC2 sections can be different from position to position.

Note: During the construction phase, the supports move to nodes N1 and N4 and the unit loads to nodes N5 and N8.

1.8 Module data

The module data that are part of the general software data are:

B: Distance between main beams

H: Height of main beams

ESS, ESI, ea: Thicknesses of the upper, lower flange and web respectively of the current section.

Data	Description
b_t	Width of manhole.
h_t	Thickness of manhole.
h_s	Distance of the top horizontal stiffener from the top fiber of the diaphragm.
BSS	Width of the upper flange of section SEC1 (length of participation of the upper flange of the main beams). Initial value 500mm.
BSI	Width of the lower flange of section SEC2 (length of participation of the lower flange of the main beams). Initial value 500mm.
b_r	Width of horizontal stiffeners
e_r	Thickness of horizontal stiffeners
b_v	Width of vertical stiffeners (=br in the case of jacking under beams)
e_v	Thickness of vertical stiffeners (=er in the case of jacking under beams)
EP	Diaphragm thickness (jacking under beams)
EP1	Thickness of central sheets (jacking under diaphragm)
EP2	Thickness of vertical sheets (jacking under diaphragm)