# PROYECTO DE CONSTRUCCIÓN DE OBRAS DE ADECUACIÓN Y MEJORA DEL EMISARIO SUBMARINO DE LA EDAR DE TÍAS (ISLA DE LANZAROTE)

Nº EXP: 12.335-0515/2111

# PROYECTO CONSTRUCTIVO

# ANEJO 11. CÁLCULOS ESTRUCTURALES (OBRA CIVIL)

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# 1. INTRODUCCIÓN Y OBJETO

El presente anejo tiene por objeto recoger el diseño, análisis y dimensionamiento estructural de los elementos que integran el *"Proyecto de construcción de obras de adecuación y mejora del emisario submarino de la EDAR de Tías (Isla de Lanzarote)"*.

El objeto del proyecto es dar cumplimiento a los requerimientos contenidos en la Resolución de la Dirección General de Calidad y Evaluación Ambiental relativa a la actuación de *"Ampliación y Mejora de la EDAR de Tías"*, declarada de interés general del Estado por la Ley 10/2001, de 5 de julio, del Plan Hidrológico Nacional, y recoge las actuaciones propuestas para rehabilitar el emisario terrestre y submarino existente de la EDAR de Tías, las cuales serán las necesarias para que el emisario de efluentes de la EDAR pueda operar como conducción de vertidos de emergencia ante situaciones excepcionales, con los caudales de diseño de la nueva ampliación de la depuradora, según se recogen en su propio proyecto de ampliación y mejora.

Para lograr este objetivo se realizan principalmente las siguientes actuaciones

- Construcción de una nueva conducción para el tramo terrestre (emisario terrestre), adaptada a los nuevos requisitos de diseño derivados de la ampliación de la EDAR y que conectará con el tramo submarino existente.
- Construcción y conexión de un nuevo tramo de difusor, cuya configuración seguirá las premisas de la solución propuesta en el informe *"Estudio de afección medioambiental, actual y futura del vertido del emisario submarino de Puerto del Carmen (Lanzarote)"* realizado por la empresa ECOS, validando y desarrollando la solución técnica descrita en dicho informe.

Se definen en el presente documento los siguientes elementos estructurales pertenecientes al tramo terrestre:

- Arquetas de ventosa.
- Arquetas de desagüe.
- Arquetas de rotura.
- Arqueta de reunión.

Los cálculos de los macizos de anclaje a disponer en los codos, tes y válvulas de la conducción se incluyen en el ***Anejo 10. Cálculos Mecánicos***.

# 2. NORMATIVA Y REFERENCIAS

## 2.1 Normas de Acciones

- Ministerio de Fomento. *"Norma de construcción sismorresistente: Parte general y edificación (NCSE-02)"*. (Real Decreto 997/2002 de 27 de septiembre de 2002).
- Ministerio de Vivienda. *"Código Técnico de la Edificación. Documento Básico SE-AE Seguridad Estructural. Acciones en la Edificación"*. (Real Decreto 314/2006 de 17 de marzo de 2006).
- *"Mapa de peligrosidad sísmica de España 2015"*, Instituto Geográfico Nacional.

## 2.2 Normas de Construcción

- Ministerio de la Presidencia. *"Código Estructural"*. (Real Decreto 470/2021 de 29 de junio de 2021).
- Eurocódigo 2: *"Proyecto de estructuras de Hormigón. Parte 2: Puentes de hormigón"* (UNE-ENV 1992-2 de diciembre de 1997).

## 2.3 Documentos de referencia

- ***Documento Nº2. Planos*** (8. Arquetas y pozos).
- ***Anejo 6. Estudio geotécnico***.

# 3. CÁLCULOS ESTRUCTURALES

## 3.1 Materiales

### 3.1.1 Hormigón

Se debe identificar el tipo de ambiente que defina la agresividad a la que va a estar sometido cada elemento estructural.

Las clases generales de exposición relativas a la corrosión de las armaduras vienen definidas en la Tabla 27.1.a. (CE)

Para la clase de hormigón a utilizar se parte de tres consideraciones:

- Agresividad del agua de mar.
- Agresividad del terreno.
- Agresividad del ambiente aéreo.

Respecto a la agresividad del terreno, nos basamos en los ensayos de agresividad recogidos en el informe geotécnico, donde se confirma que el terreno no provoca agresividad al hormigón.

Para los elementos de hormigón permanente en contacto o enterrado en suelo no agresivo, como en el caso de las arquetas, se considerará un tipo de ambiente de XC2.

Por tanto, se determina una clase de hormigón para el proyecto de HA-25/B/20/XC2

### 3.1.2 Acero para armaduras

En el Proyecto se definen:

- Acero para armaduras pasivas, en barras de refuerzo.

### 3.1.3 Acero para armaduras pasivas

De acuerdo con el Artículo 34.2 del Código Estructural los posibles diámetros nominales a emplear serán:

*6-8-10-12-16-20-25-32 y 40 mm*

En la tabla 34.2.a se definen los tipos de acero corrugado:

**Tabla 34.2.a** Tipos de acero soldable

| Tipo de acero | | Acero soldable | | Acero soldable con características especiales de ductilidad | |
|---|---|---|---|---|---|
| Designación | | B 400 S | B 500 S | B 400 SD | B 500 SD |
| Límite elástico, $f_y$ (N/mm²) (1) | | ≥ 400 | ≥ 500 | ≥ 400 | ≥ 500 |
| Carga unitaria de rotura, $f_s$ (N/mm²) (1) | | ≥ 440 | ≥ 550 | ≥ 480 | ≥ 575 |
| Alargamiento de rotura, $\varepsilon_{u,5}$ (%) | | ≥ 14 | ≥ 12 | ≥ 20 | ≥ 16 |
| Alargamiento total bajo carga máxima, $\varepsilon_{máx}$ (%) | acero suministrado en barra | ≥ 5,0 | ≥ 5,0 | ≥ 7,5 | ≥ 7,5 |
| | acero suministrado en rollo (3) | ≥ 7,5 | ≥ 7,5 | ≥ 10,0 | ≥ 10,0 |
| Relación $f_s/f_y$ (2) | | ≥ 1,08 | ≥ 1,08 | $1{,}20 \le f_s/f_y \le 1{,}35$ | $1{,}15 \le f_s/f_y \le 1{,}35$ (4) |
| Relación $f_{y\,real}/f_{y\,nominal}$ | | – | – | ≤ 1,20 | ≤ 1,25 |

(1) Para el cálculo de los valores unitarios se utilizará la sección nominal.

(2) Relación admisible entre la carga unitaria de rotura y el límite elástico obtenidos en cada ensayo.

(3) En el caso de aceros procedentes de suministros en rollo, los resultados pueden verse afectados por el método de preparación de la muestra para su ensayo, que deberá hacerse conforme a lo indicado en el Anejo 11. Considerando la incertidumbre que puede conllevar dicho procedimiento, pueden aceptarse aceros que presenten valores característicos de $\varepsilon_{máx}$ que sean inferiores en un 0,5% a los que recoge la tabla para estos casos.

(4) En el caso de la utilización de aceros soldables inoxidables dúplex o austeníticos como medida especial de durabilidad, debido a su relación constitutiva de tensión-deformación específica, la relación se calcula utilizando el valor de $f_y$ 7% en lugar de $f_s$

## 3.2 Recubrimiento del hormigón

### 3.2.1 Vida útil

Las estructuras de hormigón deberán ser idóneas para su uso, durante la totalidad de su vida útil para la que se construye.

De acuerdo con la tabla 2.1 del Anejo 18 del Código Estructural en el punto 2.3, se considera una categoría 5 de vida útil y una vida útil nominal de 100 años:

**Tabla 2.1** Vida útil nominal

| Categoría de vida útil | Vida útil nominal (años) | Ejemplos |
|---|---|---|
| 1 | 10 | Estructuras temporales(1) |
| 2 | 10 a 25 | Partes reemplazables de la estructura, por ejemplo vigas carril, aparatos de apoyo |
| 3 | 15 a 30 | Estructuras agrícolas y similares |
| 4 | 50 | Estructuras de edificación y otras estructuras comunes |
| 5 | 100 | Estructuras de edificios monumentales, puentes y otras estructuras de ingeniería civil |

(1) Las estructuras o partes de estructuras que pueden desmontarse con vistas a ser reutilizadas no deben considerarse como temporales.

De acuerdo con el artículo 44 del CE se obtiene el siguiente recubrimiento:

**Tabla 44.2.1.1.a** Recubrimientos mínimos (mm), $C_{min}$, para las clases de exposición relacionadas con la corrosión por carbonatación

| Clase de exposición | Tipo de cemento | Resistencia característica del hormigón [N/mm²] | Vida útil de proyecto ($t_L$), (años) | |
|---|---|---|---|---|
| | | | 50 | 100 |
| X0 | Cualquiera | $fck \geq 25$ | 15 | 25 |
| XC1, XC2 ó XC3 | CEM I | $25 \leq fck < 40$ | 15 | 25 |
| | | $fck \geq 40$ | 10 | 20 |
| | Otros tipos de cementos o en el caso de empleo de adiciones al hormigón | $25 \leq fck < 40$ | 20 | 30 |
| | | $fck \geq 40$ | 15 | 25 |
| XC4 | CEM I | $25 \leq fck < 40$ | 20 | 30 |
| | | fck ≥ 40 | 15 | 25 |
| | Otros tipos de cementos o en el caso de empleo de adiciones al hormigón | $25 \leq fck < 40$ | 25 | 35 |
| | | $fck \geq 40$ | 20 | 30 |

Para el presente proyecto se adoptará un recubrimiento mínimo de 50mm en condiciones normales, y de 75mm para los elementos hormigonados contra el terreno.

## 3.3 Abertura máxima de fisura

**Tabla AN/9 (Tabla 7.1N).Abertura máxima de la fisura**

| Clase de exposición | $w_{max}$ (mm) | |
|---|---|---|
| | Hormigón armado (para la combinación cuasipermanente de acciones) | Hormigón pretensado (para la combinación frecuente de acciones) |
| XO[2], XC1[4] | 0.4 | 0.2 |
| XC1[4], XC2, XC3, XF1, XF3, XC4 | 0.3 | 0.2[1] |
| XS1, XS2, XD1, XD2, XD3, XF2, XF4, XA1[3] | 0.2 | Descompresión |
| XS3, XA2[3], XA3[3] | 0.1 | |

» [1] Adicionalmente deberá comprobarse que las armaduras activas se encuentran en la zona comprimida de la sección, bajo la combinación cuasipermanente de acciones.
» [2] Para las clases de exposición XO y XC1, la abertura de fisura no influye normalmente en la durabilidad. Los valores recogidos en la tabla para estos casos se establecen para garantizar un aspecto aceptable.
» [3] La limitación relativa a las clases XA1, XA2 y XA3 sólo será de aplicación en el caso de que el ataque químico pueda afectar a la armadura. En otros casos, se aplicará la limitación correspondiente a la clase general correspondiente.
» [4] La definición de la clase XC1 recogida en el Eurocódigo se corresponde parcialmente con las clases I y IIa definidas en la Instrucción de Hormigón Estructural EHE-08, por lo que el Autor del proyecto aplicará la limitación menos exigente de la apertura de fisura recogida en la segunda fila de la tabla, sólo cuando se trate de elementos interiores de edificios protegidos de la intemperie.

## 3.4 Acciones de diseño

### 3.4.1 Cargas permanentes

Se refiere a los pesos de los elementos que constituyen la obra y se supone que actúan en todo momento, siendo constante en magnitud

**Peso Propio**

La carga se deduce de la geometría teórica de los distintos elementos, considerando su densidad. Fundamentalmente son los siguientes:

- Hormigón armado: 25,00 kN/m$^3$.
- Hormigón en masa: 23,00 kN/m$^3$.

**Acciones gravitatorias del terreno**

Se obtienen de acuerdo con la geometría de los rellenos sobre los elementos estructurales considerando una densidad del terreno de 20,00 kN/m$^3$, salvo que se especifique lo contrario.

### 3.4.2 Acciones Permanentes de Valor no Constante

Son acciones que van cambiando con el tiempo y que pueden o no producir esfuerzos, en función de las vinculaciones de los elementos estructurales.

**Acciones del Terreno sobre Muros**

En este apartado se consideran las acciones originadas por el terreno natural o de relleno, sobre los elementos de la estructura en contacto con él. Los valores considerados para el cálculo de los empujes son los siguientes:

- Peso específico aparente: $\gamma$ = 20,00 kN/m$^3$
- Cohesión: c = 0,00 kPa
- Ángulo de rozamiento interno: $\alpha = 35^{\circ}$
- Ángulo de rozamiento terreno-muro: $\delta = 23{,}3^{\circ}$ y ángulo superficie talud: $\beta = 0^{\circ}$

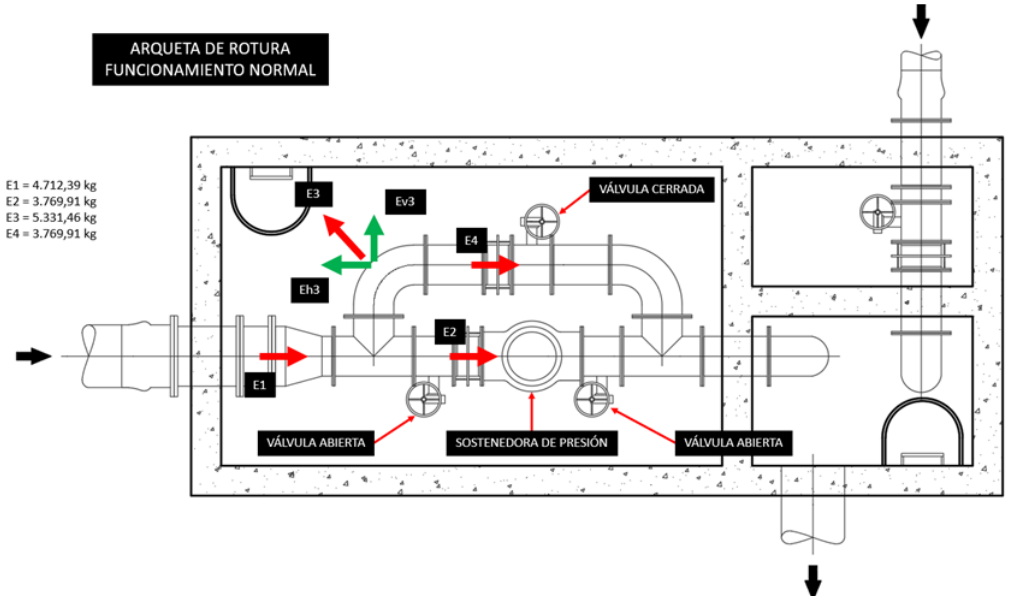
No se considera freático en el terreno.

### 3.4.3 Acciones Variables

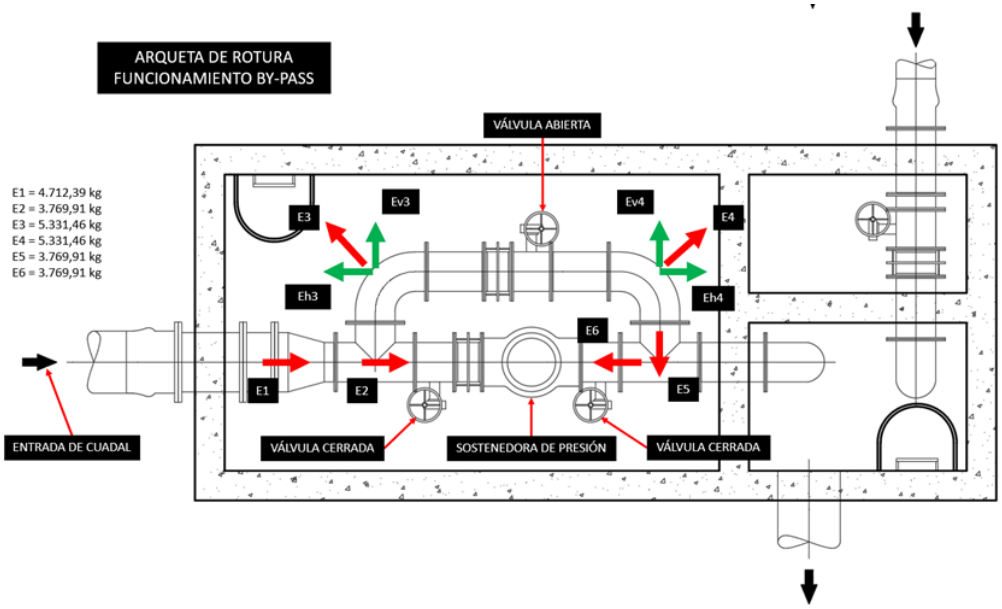
**Reacciones de la tubería en la arqueta de rotura**

Se consideran dos casos de funcionamiento:

- Funcionamiento normal




- Funcionamiento by-pass




**Acciones Accidentales**

Son fundamentalmente el sismo, el incendio y los posibles impactos.

**Acción del sismo**

Los criterios de aplicación de la NCSE-02 son los que se indican en el apartado 1.2.3 de dicha norma, según la cual no es obligatorio aplicar dicha norma en los siguientes casos:

- En las construcciones de importancia moderada.
- En las edificaciones de importancia normal o especial cuando la aceleración sísmica básica, ab, sea inferior a 0,04 g, siendo g la aceleración de la gravedad.

- En las construcciones de importancia normal, con pórticos bien arriostrados entre sí en todas las direcciones, cuando la aceleración sísmica básica, ab, sea inferior a 0,08 g.

Según lo establecido en el Anejo I de la Norma, para la zona de estudio, la provincia de Las Palmas:

ab = 0,04 g

ab < 0,08 g

Por lo tanto, no se considera acción del sismo

## 3.5 Combinaciones de cargas

El valor representativo de una acción es el valor de la misma utilizado para la comprobación de los Estados Límites, de acuerdo con el Artículo 4.1.2 Anejo 18 del Código Estructural. El valor representativo de una acción se obtiene afectando su valor característico, $F_k$, por un factor:

$$\Psi_i F_k$$

Como valores representativos se consideran los indicados en la reglamentación específica aplicable. En este caso el Código Estructural.

Las acciones se definen, en su magnitud, por sus valores representativos.

Una misma acción puede tener un único o varios valores representativos, según se indica a continuación, en función del tipo de acción.

Para las acciones permanentes se considerará un único valor representativo, coincidente con el valor característico $G_k$.

Para las acciones Permanentes de Valor no Constante (G*) hay distintos casos:

- Acciones originadas por presolicitaciones: Se considerará para las acciones originadas por las presolicitaciones un único valor representativo, coincidente con el valor característico $P_{k,t}$, correspondiente al instante *"t"* en el que se realiza la comprobación.
- Reológicas: Se considerará para las acciones de origen reológico un único valor representativo, coincidente con el valor característico $R_{k,t}$, correspondiente al instante "t" en el que se realiza la comprobación.
- Acciones del terreno: Para el peso del terreno, que gravita sobre elementos de la estructura, se considerará un único valor representativo, coincidente con el valor característico.

Cada una de las acciones variables puede considerarse con los siguientes valores representativos:

- Valor característico $Q_k$: Valor de la acción cuando actúa aisladamente.
- Valor de combinación $\Psi_0$ $Q_k$: Valor de la acción cuando actúa en compañía de alguna otra acción variable.
- Valor frecuente $\Psi_1$ Qk: Valor de la acción que es sobrepasado durante un período de corta duración respecto a la vida útil de la estructura.

- Valor cuasi permanente $\Psi_2$ $Q_k$: Valor de la acción que es sobrepasado durante una gran parte de la vida útil de la estructura.

Los valores de los coeficientes de simultaneidad (Ψ), según el Código Técnico de la Edificación, son los siguientes:

| Acción | $\Psi_0$ | $\Psi_1$ | $\Psi_2$ |
|---|---|---|---|
| Viento | 0,60 | 0,50 | 0,00 |
| Temperatura | 0,60 | 0,50 | 0,00 |
| Nieve | 0,50 | 0,20 | 0,00 |
| Sobrecargas de Uso | 0,70 | 0,70 | 0,60 |
| Sobrecarga Mantenimiento | 0,00 | 0,00 | 0,00 |
| Acciones Variables Terreno | 0,70 | 0,70 | 0,70 |

### 3.5.1 Valores de cálculo de las acciones

Se define como valor de cálculo de una acción el obtenido como producto de un coeficiente parcial de seguridad por el valor representativo de la misma.

Los coeficientes de seguridad a aplicar son distintos en función de los Estados Límites que se estén comprobando.

**Estados Límites Últimos (E.L.U.)**

Los coeficientes de seguridad utilizados para las comprobaciones de resistencia en Estados Límite Últimos del hormigón estructural como establece el Anejo 18 del CE y el artículo 2.3.3 del Eurocódigo 2-4 son:

| COEFICIENTES DE SEGURIDAD DE ACCIONES EN ELU | | |
|---|---|---|
| TIPO DE ACCIÓN | SITUACIÓN PERSISTENTE O TRANSITORIA | |
| | EFECTO | |
| | FAVORABLES ($\gamma_G$) | DESFAVORABLE ($\gamma_G$) |
| Peso propio y cargas muertas | 0,80 | 1,35 |
| Empuje del terreno | 0,70 | 1,35 |
| Agua en el terreno (1) | 0,90 | 1,20 (1) |
| Líquido (intradós) (2) | 0,00 | 1,20 (2) |
| Variable | 0,00 | 1,50 |
| NOTAS:<br>(1) DB SE Tabla 4.1<br>(2) Eurocódigo 2-4. Tabla 2.102 | | |

**Estados Límites de Servicio (E.L.S.)**

Los coeficientes de seguridad utilizados para las comprobaciones de los Estados Límite de Servicio tal y como establece el Anejo 18 del CE:

| COEFICIENTES DE SEGURIDAD DE ACCIONES EN E.L.S. | | |
|---|---|---|
| TIPO DE ACCIÓN | EFECTO | |
| | FAVORABLES ($\gamma_G$) | DESFAVORABLE ($\gamma_G$) |
| Permanente | 1,00 | 1,00 |
| Agua en el terreno | 1,00 | 1,00 |
| Líquido (intradós) (2) | 0,00 | 1,00 |
| Variable | 0,00 | 1,00 |

### 3.5.2 Combinación de acciones

Para cada una de las situaciones estudiadas se establecerán las posibles combinaciones de acciones. Una combinación de acciones consiste en un conjunto de acciones que se consideran actuando simultáneamente para una comprobación determinada.

Cada combinación estará formada por las acciones permanentes, una acción variable determinante y una o varias acciones variables concomitantes. Cualquiera de las acciones variables puede ser determinante.

**Estados Límites Últimos (E.L.U.)**

Para las distintas situaciones de Proyecto, las combinaciones de acciones se definen de acuerdo con los criterios que se incluyen a continuación.

Situaciones permanentes o transitorias

Las combinaciones de las distintas acciones consideradas en estas situaciones se realizarán de acuerdo con el siguiente criterio:

$$\sum_{i\geq 1}\gamma_{G,i}\cdot G_{k,i}+\sum_{j\geq 1}\gamma_{G^*,j}\cdot G^*_{k,j}+\gamma_P\cdot P_k+\gamma_{Q,1}\cdot Q_{k,1}+\sum_{i>1}\gamma_{Q,i}\Psi_{0,i}\cdot Q_{k,i}$$

Donde:

$G_{k,i}$ = Valor representativo de cada acción permanente.

$G^*_{k,j}$ = Valor representativo de cada acción permanente de valor no constante.

$P_k$ = Valor característico de la acción del pretensado

$Q_{k,1}$ = Valor característico de la acción variable dominante.

$\Psi_{0,i}\bullet Q_{k,i}$ = Valores de combinación de las acciones variables concomitantes con la acción variable domi-nante.

Situaciones accidentales sin sismo

Las combinaciones de las distintas acciones consideradas en estas situaciones se realizarán de acuerdo con el siguiente criterio:

$$\sum_{i\geq 1}\gamma_{G,i}\cdot G_{k,i}+\sum_{j\geq 1}\gamma_{G^*,j}\cdot G^*_{k,j}+\gamma_P\cdot P_k+\gamma_{Q,1}\cdot\Psi_{1,1}\cdot Q_{k,1}+\sum_{i>1}\gamma_{Q,i}\Psi_{2,i}\cdot Q_{k,i}+\gamma_A\cdot A_k$$

Donde:

$G_{k,i}$ = Valor representativo de cada acción permanente.

$G^*_{k,j}$ = Valor representativo de cada acción permanente de valor no constante.

$P_k$ = Valor característico de la acción del pretensado.

$\Psi_{1,1}\bullet Q_{k,1}$ = Valores frecuente de la acción variable dominante.

$\Psi_{2,i}\bullet Q_{k,i}$ = Valores casi-permanentes de las acciones variables concomitantes con la acción variable dominante y la acción accidental.

$A_k$ = Valor característico de la acción accidental.

**Estados Límites de Servicio (E.L.S.)**

Para estos estados se consideran únicamente las situaciones persistentes y transitorias, excluyéndose las accidentales. Las combinaciones de las diferentes acciones consideradas en estas situaciones se realizarán de acuerdo con los siguientes criterios:

Combinación característica (poco probable o rara)

$$\sum_{i\geq 1}\gamma_{G,i}\cdot G_{k,i}+\sum_{j\geq 1}\gamma_{G^*,j}\cdot G^*_{k,j}+\gamma_P\cdot P_k+\gamma_{Q,1}\cdot Q_{k,1}+\sum_{i>1}\gamma_{Q,i}\cdot\Psi_{0,i}\cdot Q_{k,i}$$

Combinación frecuente

$$\sum_{i\geq 1}\gamma_{G,i}\cdot G_{k,i}+\sum_{j\geq 1}\gamma_{G^*,j}\cdot G^*_{k,j}+\gamma_P\cdot P_k+\gamma_{Q,1}\cdot\Psi_{1,1}\cdot Q_{k,1}+\sum_{i>1}\gamma_{Q,i}\cdot\Psi_{2,i}\cdot Q_{k,i}$$

Combinación casi-permanente

$$\sum_{i\geq 1}\gamma_{G,i}\cdot G_{k,i}+\sum_{j\geq 1}\gamma_{G^*,j}\cdot G^*_{k,j}+\gamma_P\cdot P_k+\sum_{i>1}\gamma_{Q,i}\cdot\Psi_{2,i}\cdot Q_{k,i}$$

## 3.6 Coeficiente minoración de materiales

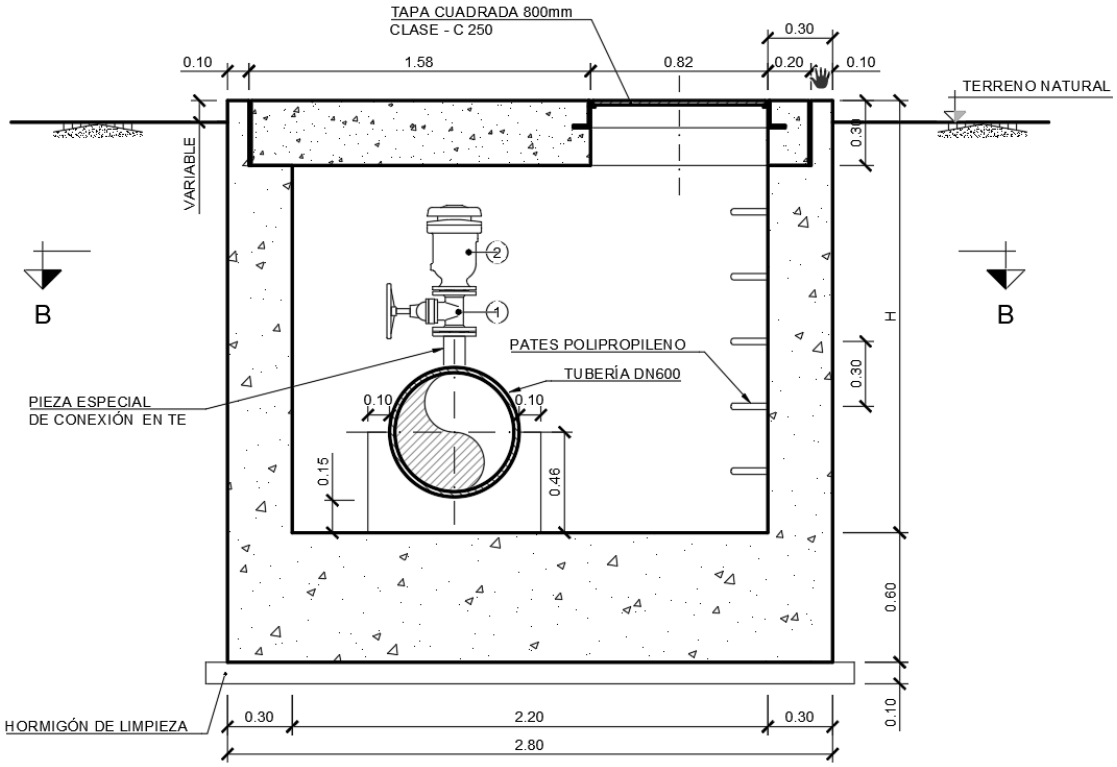
Se considerarán los siguientes coeficientes de minoración de materiales:

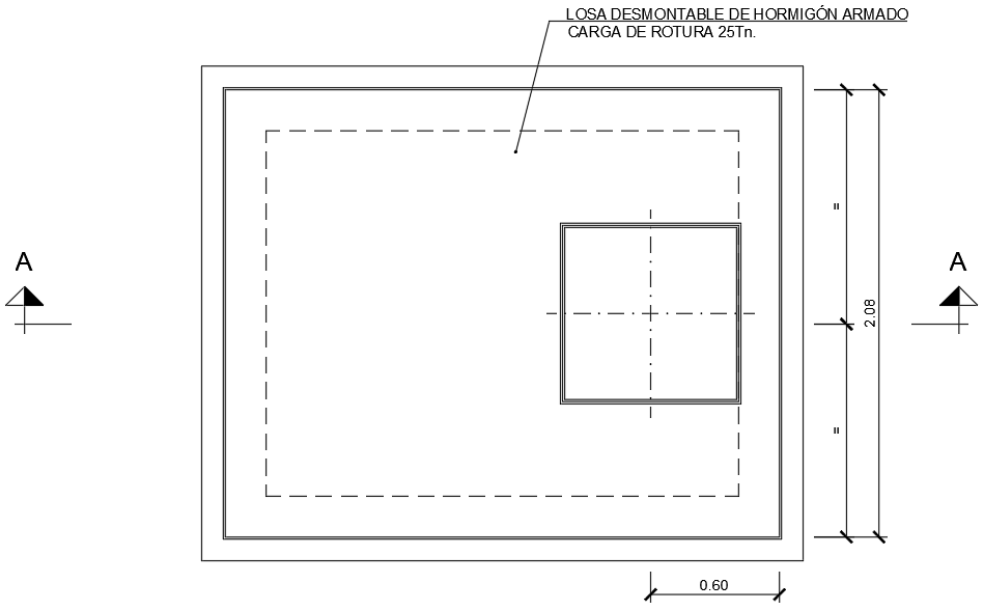
- Hormigón: $\gamma_c$=1,50
- Acero (armado): $\gamma_s$ =1,15

## 3.7 Definición geométrica

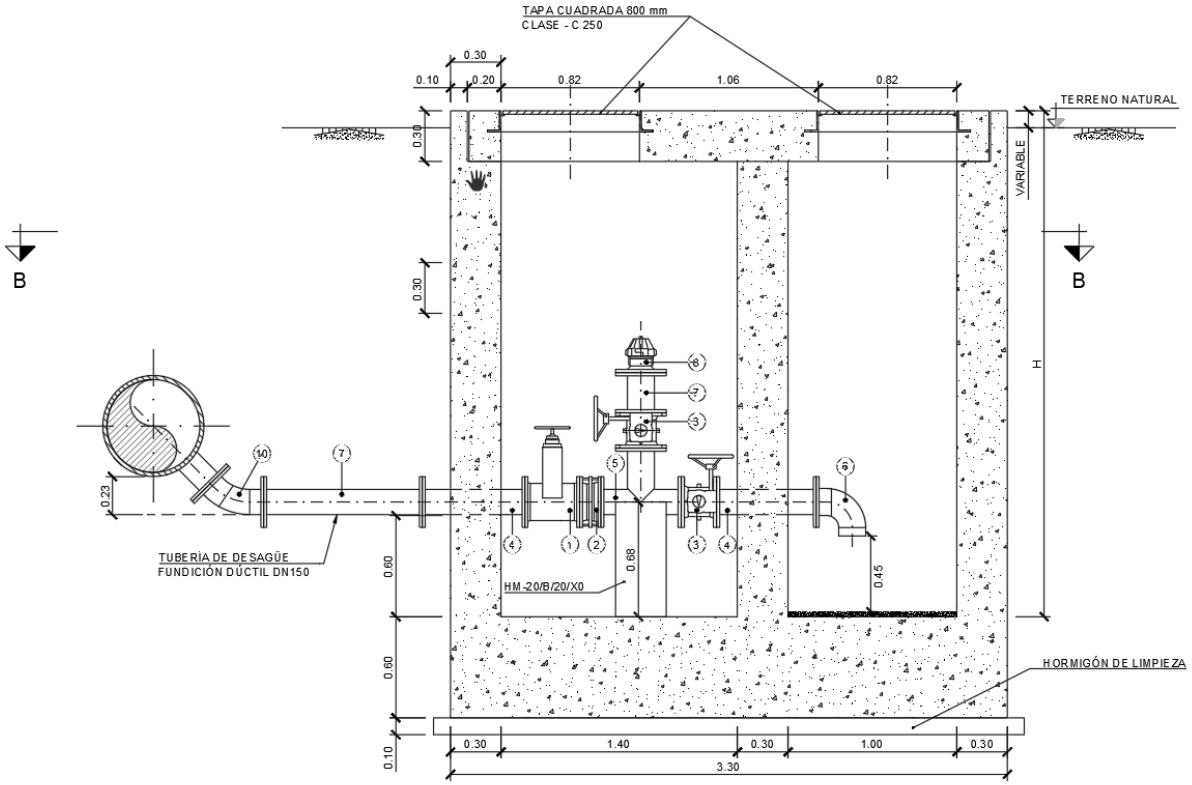
A continuación, se muestra la definición geométrica de las distintas arquetas, cuyo tamaño es variable y depende de los requerimientos hidráulicos. Para el cálculo se ha analizado para el caso mayor de cada tipología.

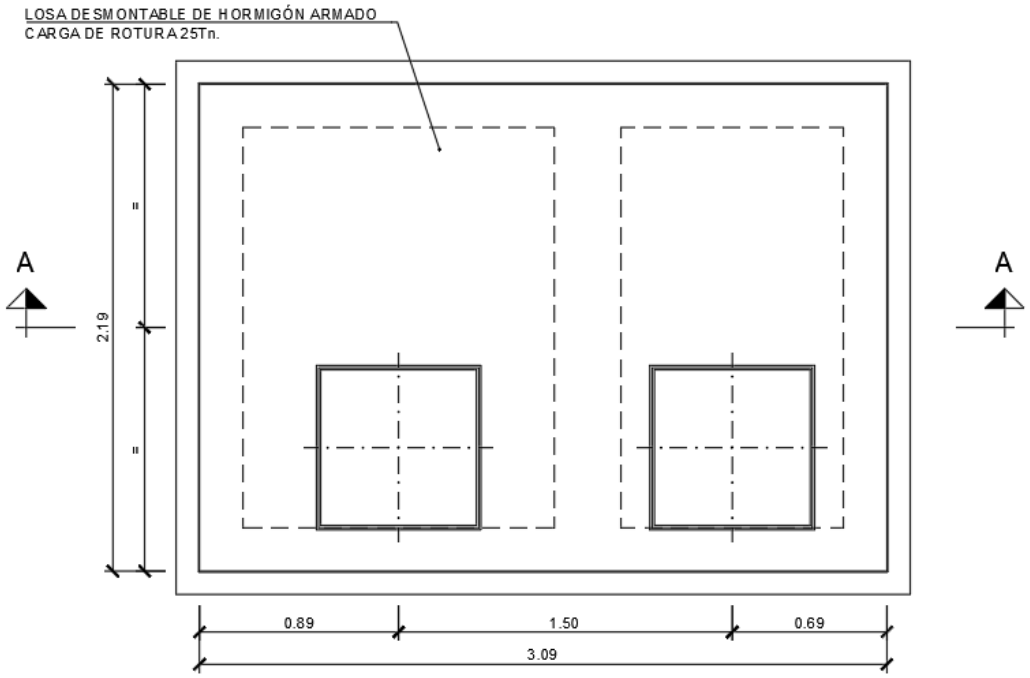
### 3.7.1 Arqueta de ventosa



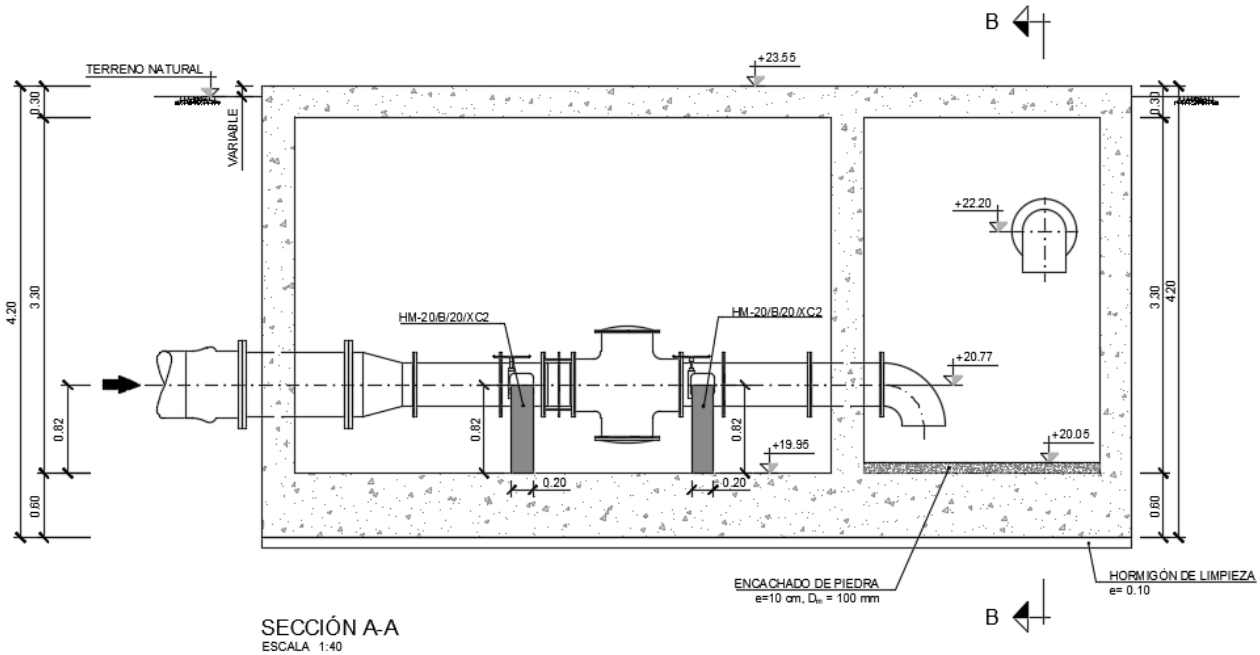



### 3.7.2 Arqueta de desagüe

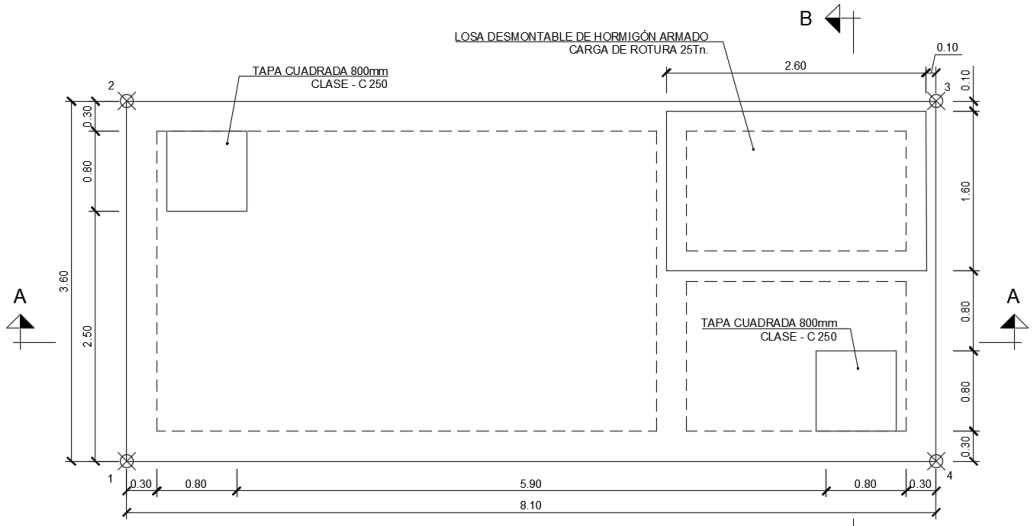


### 3.7.3 Arqueta de rotura

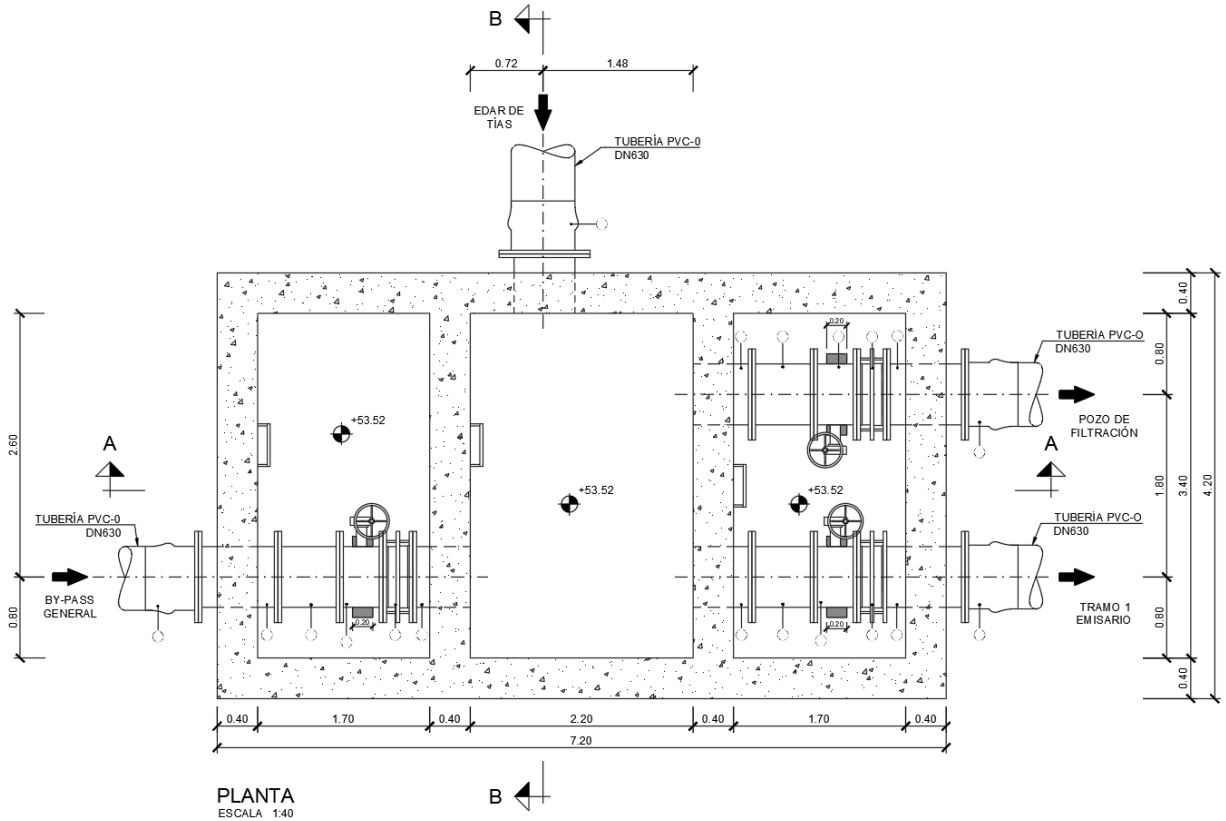



SECCIÓN A-A
ESCALA 1:40

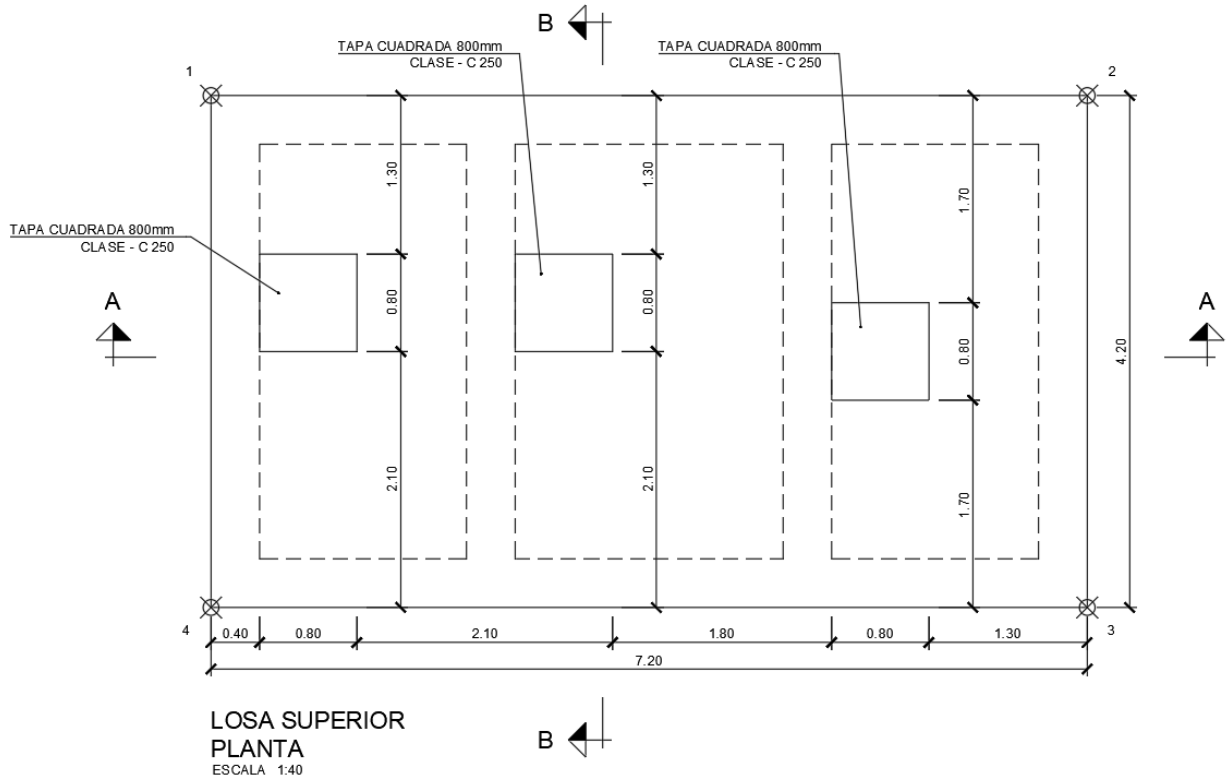



LOSA SUPERIOR
PLANTA
ESCALA 1:40

### 3.7.4 Arqueta de reunión




PLANTA
ESCALA 1:40




LOSA SUPERIOR
PLANTA
ESCALA 1:40

## 3.8 Modelo de cálculo. Arqueta de ventosa

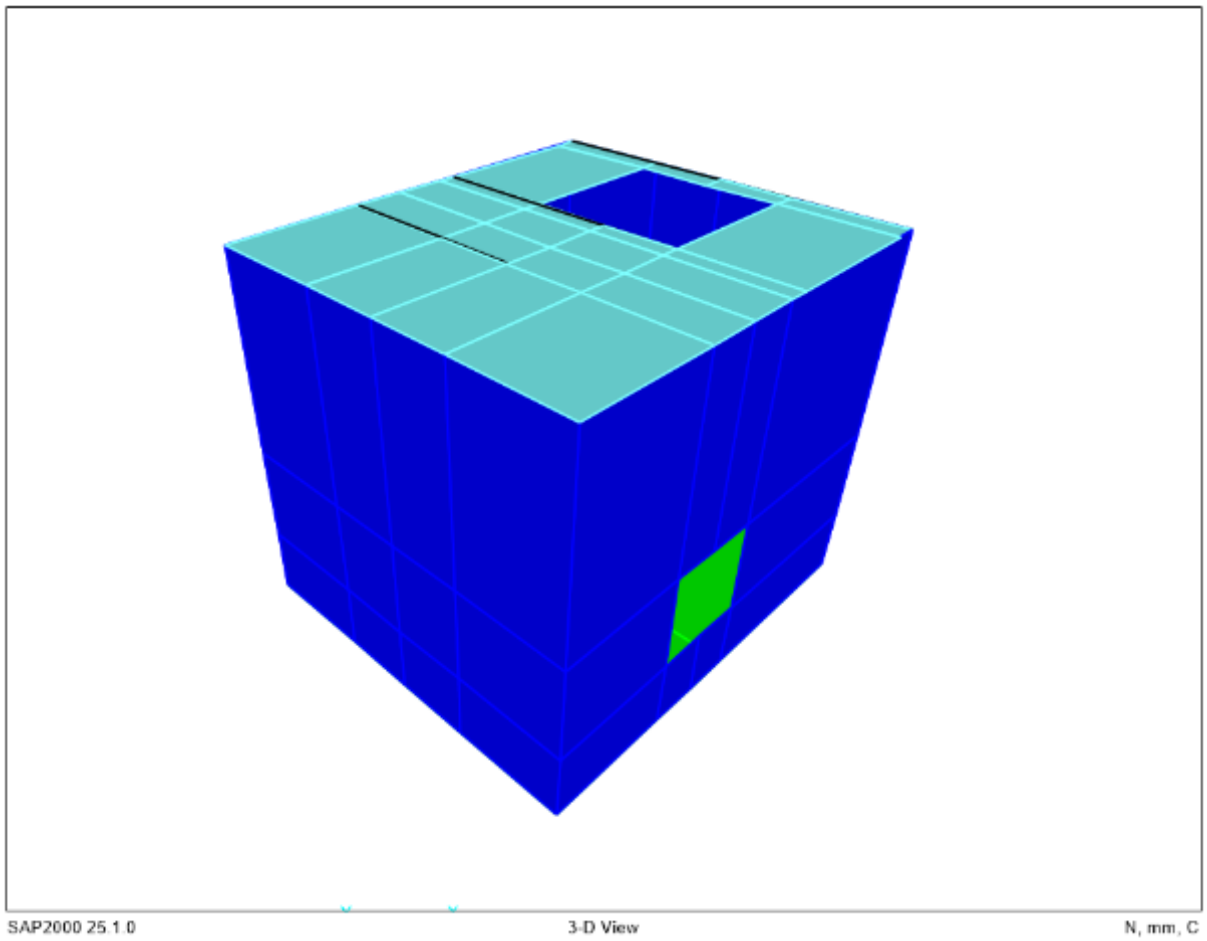
El cálculo estructural se realiza acorde al método global de análisis utilizado para cálculo de fuerzas y momentos internos de los miembros, mediante un modelo tridimensional, con el software de diseño estructural SAP2000 v25.1.0.

Este software utiliza el método de análisis elástico que puede usarse en todos los casos. El programa se basa en técnicas de cálculo matricial y elementos finitos bajo las habituales hipótesis de elasticidad lineal:

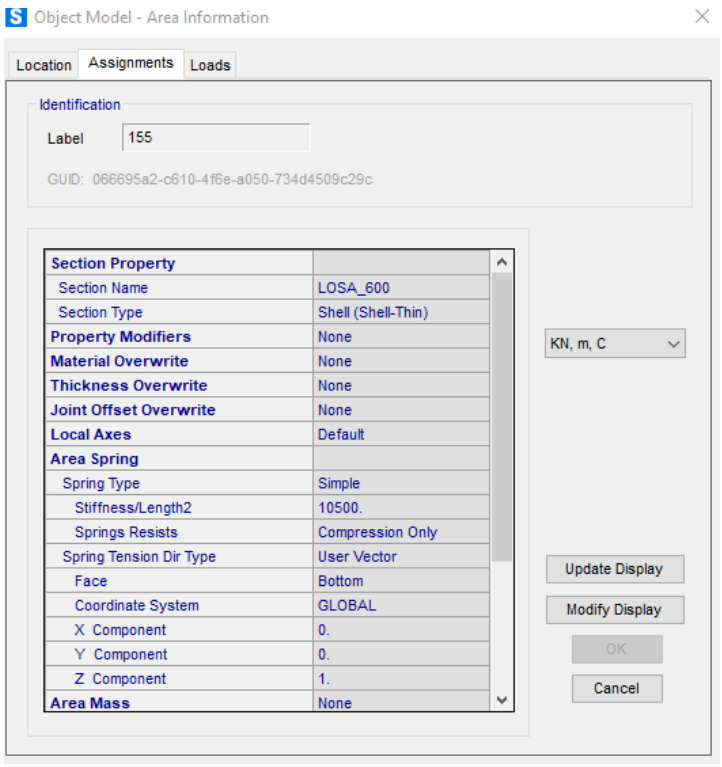
- Proporcionalidad entre tensiones y deformaciones.
- Compatibilidad de elementos estructurales.
- Balance estático local y global de cada una de las partes de la estructura

### 3.8.1 Geometría

Los muros y losas que forman la arqueta se representan mediante elementos tipo «Shell» de distintos espesores.



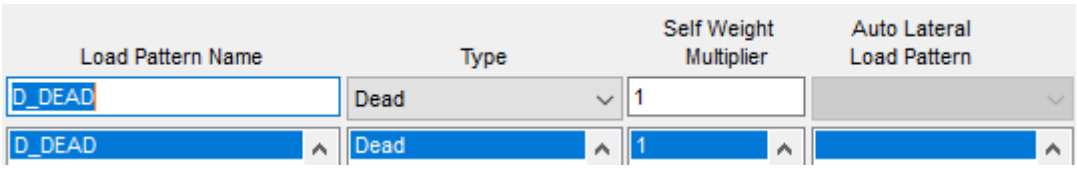

El módulo de balasto considerado según el terreno en la cimentación es de 10500 kN/m$^3$.



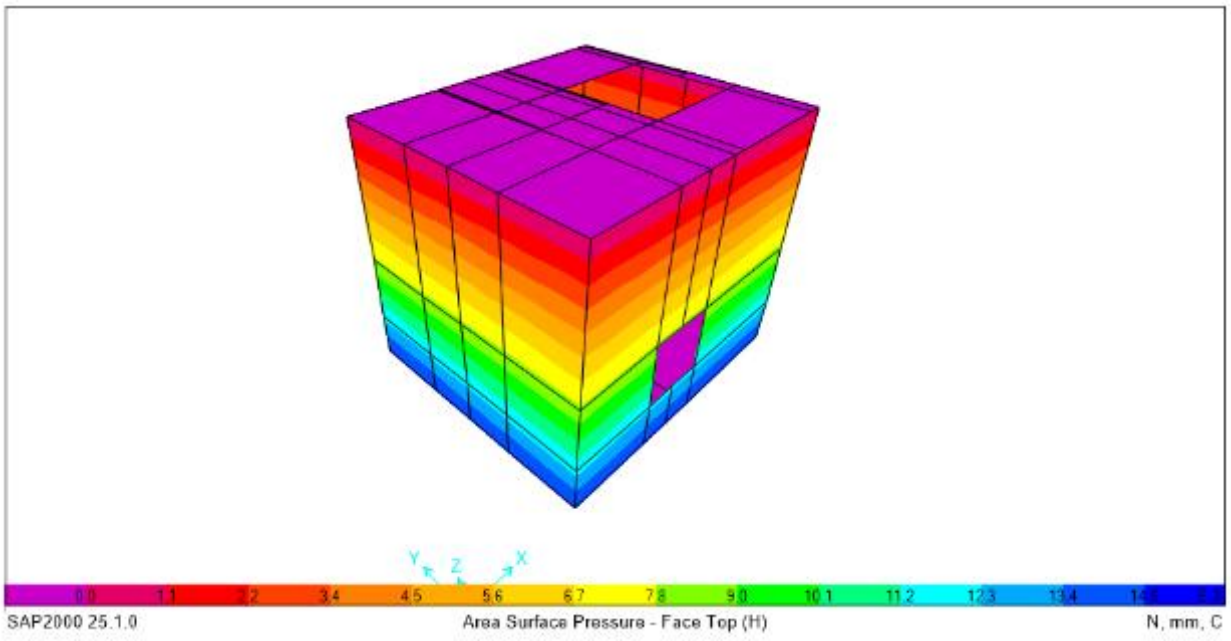

### 3.8.2 Acciones de cálculo en el modelo

**Peso propio**

El peso propio de los elementos (muros y losas de hormigón) SAP2000 lo introduce directamente con las definiciones que se han hecho de las propiedades de los elementos y los materiales. En el programa esta acción se denomina DEAD.



**Empuje del terreno**

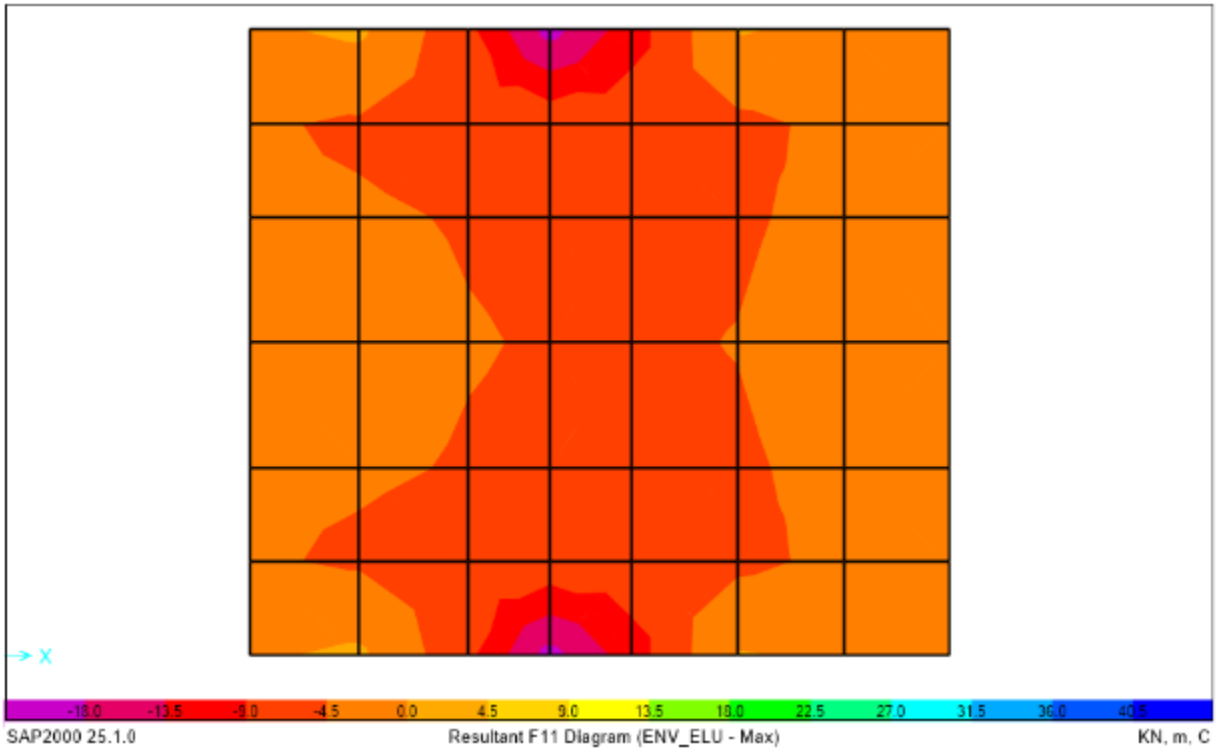


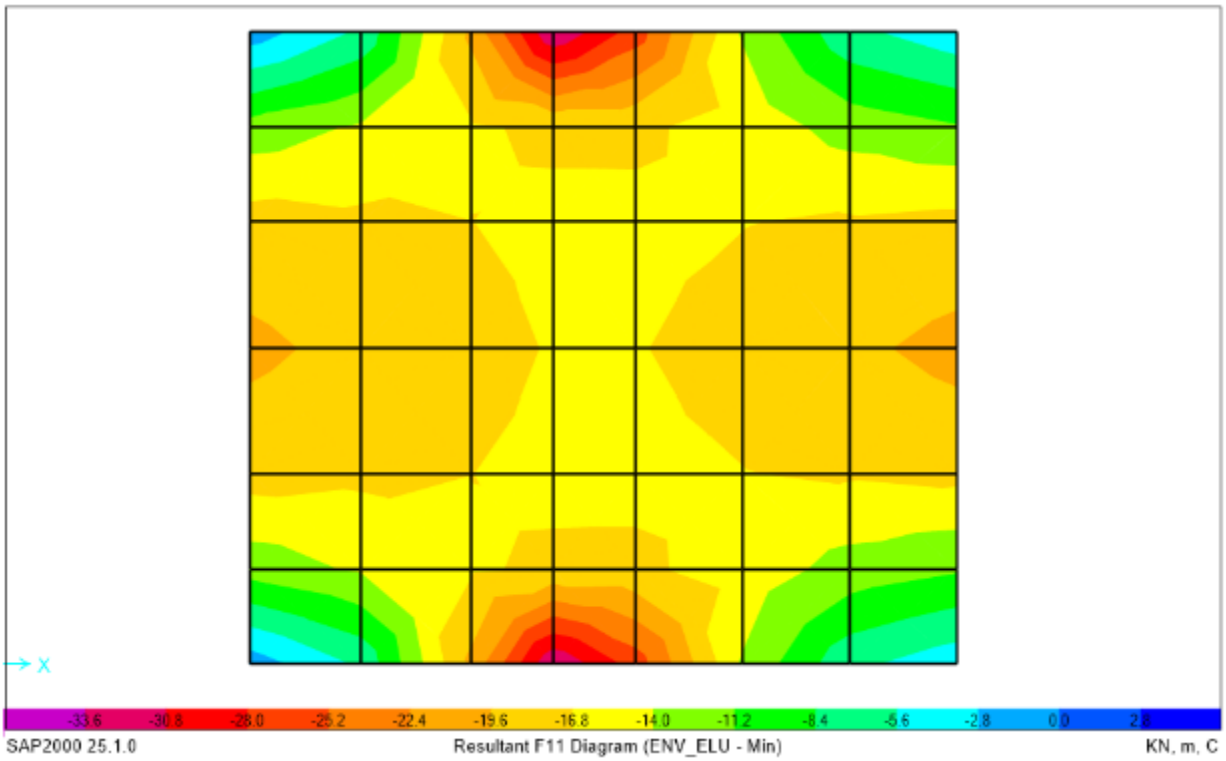

### 3.8.3 Resultados

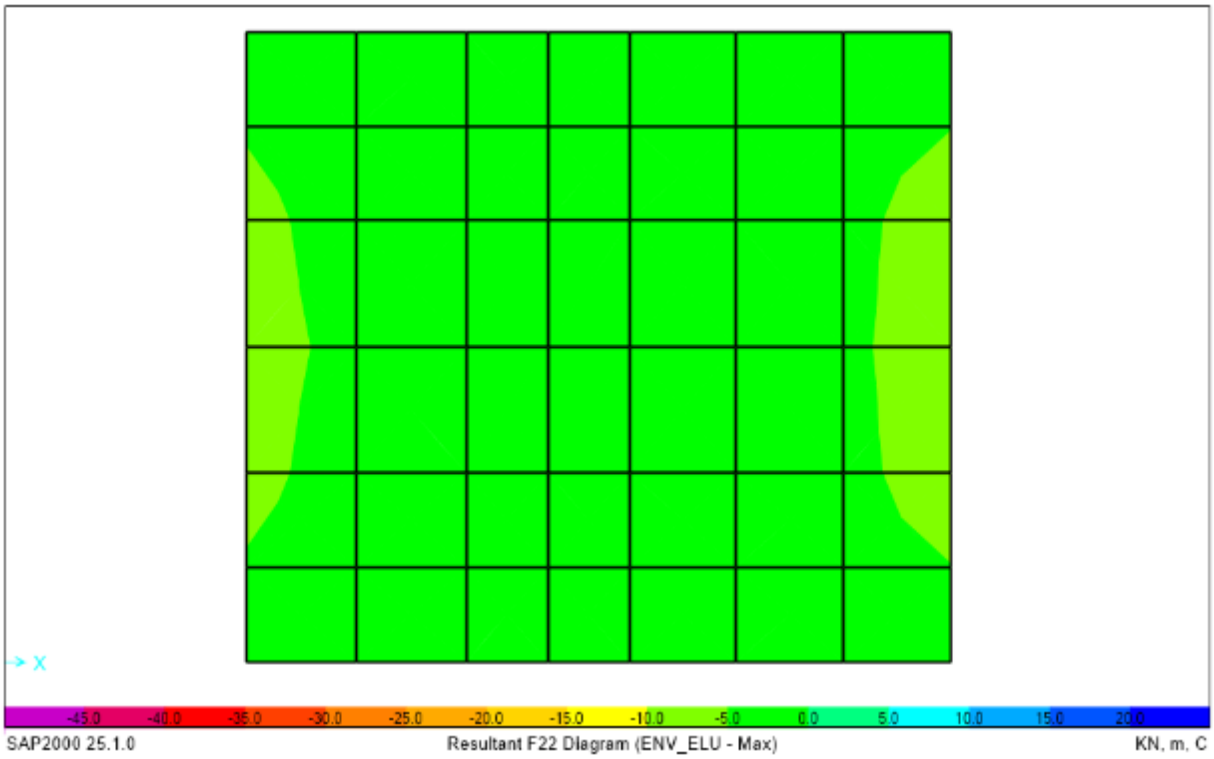
A continuación, se muestran los resultados del modelo para cada elemento estructural, diferenciando en losa inferior, muros, columnas y losa superior para todas las situaciones de diseño.

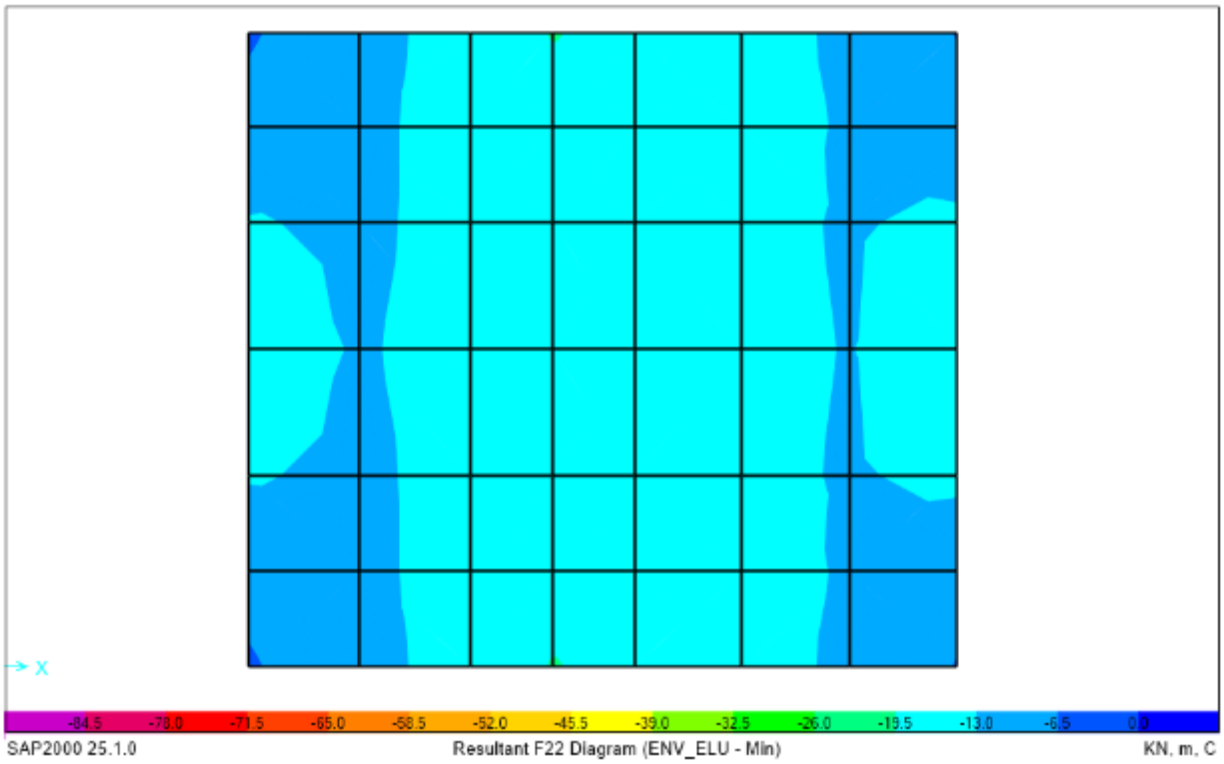
**Losa base inferior**

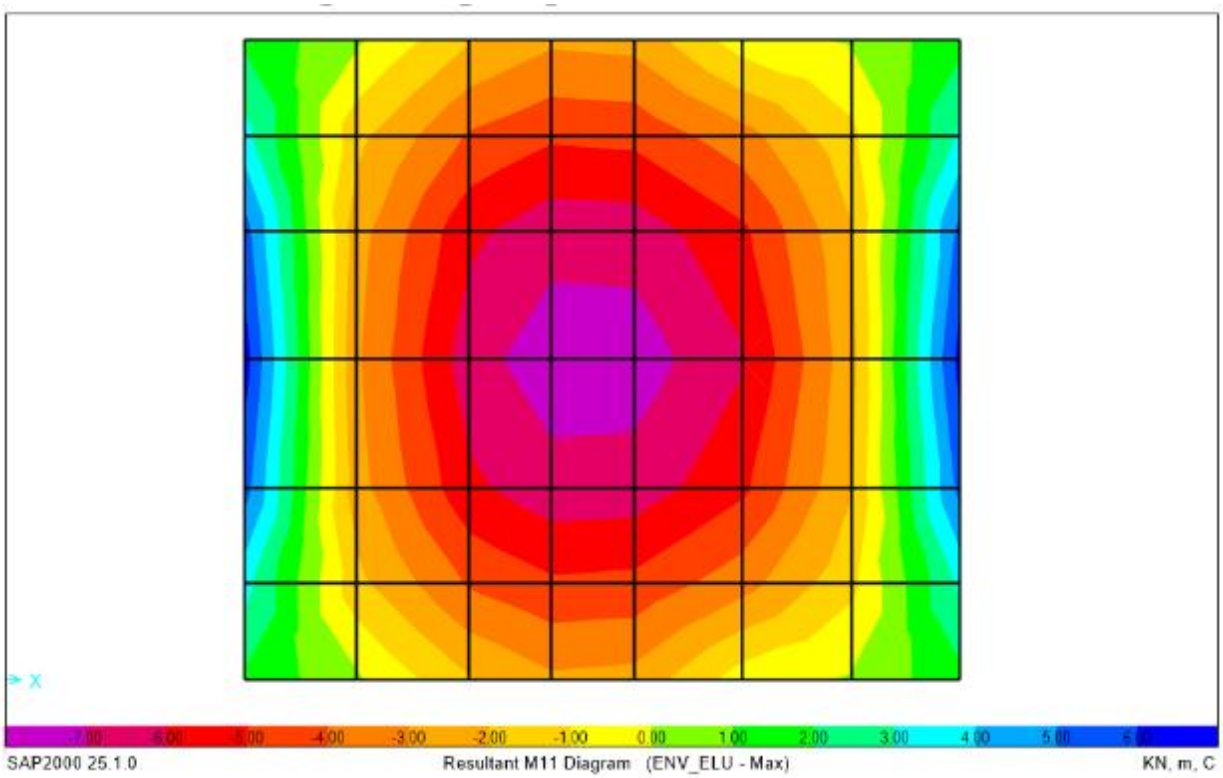
| LOSA BASE INFERIOR – ELU RESULTADOS | | | | | |
|---|---|---|---|---|---|
| | **$F_{11}$ (kN)** | **$M_{11}$ (kNm)** | **$F_{22}$ (kN)** | **$M_{22}$ (kNm)** | **$V_{max}$ (kN)** |
| **ELU (min)** | -36,11 | -15,05 | -20,29 | -15,7 | 3,81 |
| **ELU (max)** | 2,21 | 6,41 | 0,41 | 5,6 | 31,47 |

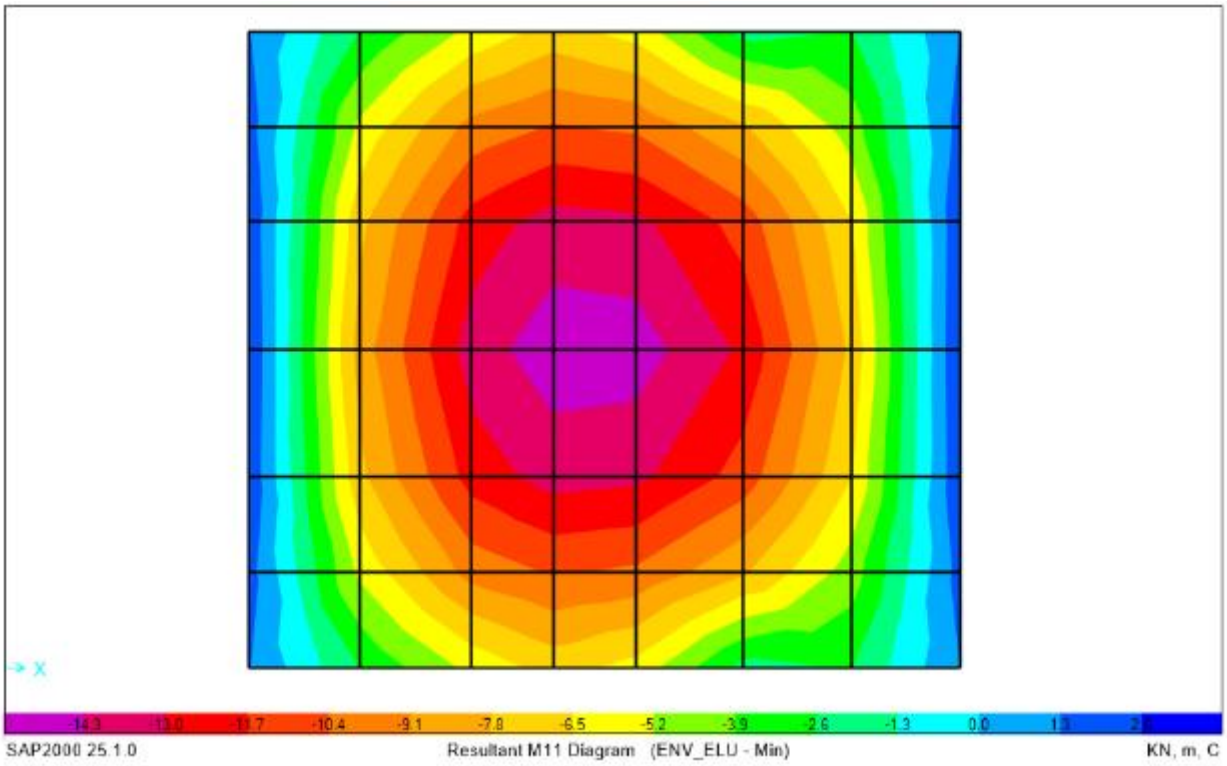

X
-18.0 -13.5 -9.0 -4.5 0.0 4.5 9.0 13.5 18.0 22.5 27.0 31.5 36.0 40.5
SAP2000 25.1.0
Resultant F11 Diagram (ENV_ELU - Max)
KN, m, C

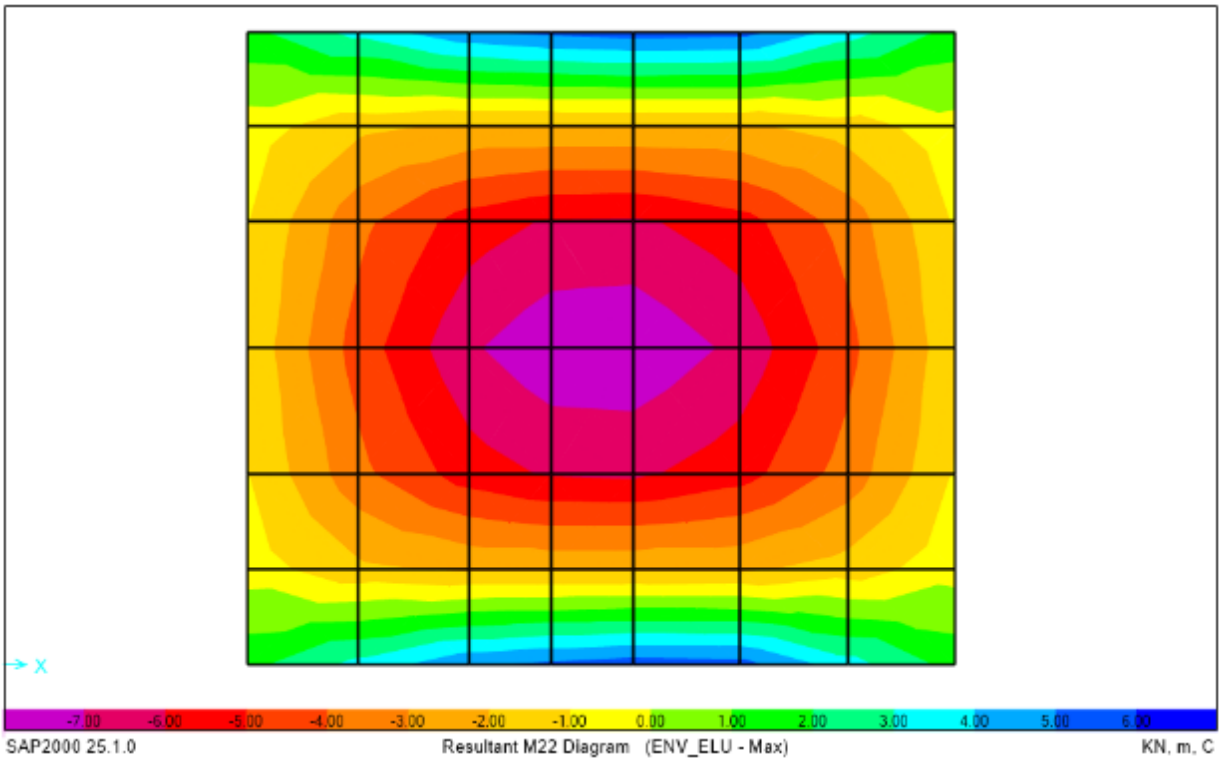

X
-33.6 -30.8 -28.0 -25.2 -22.4 -19.6 -16.8 -14.0 -11.2 -8.4 -5.6 -2.8 0.0 2.8
SAP2000 25.1.0
Resultant F11 Diagram (ENV_ELU - Min)
KN, m, C

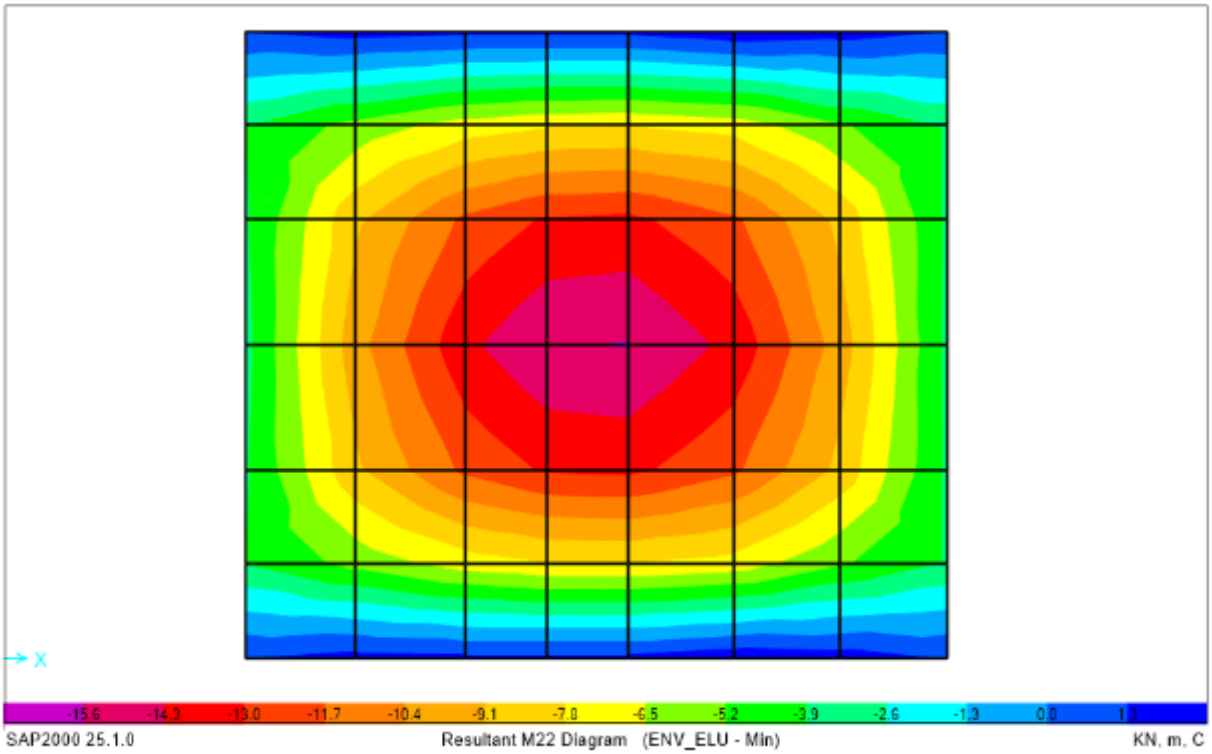

X
-45.0 -40.0 -35.0 -30.0 -25.0 -20.0 -15.0 -10.0 -5.0 0.0 5.0 10.0 15.0 20.0
SAP2000 25.1.0
Resultant F22 Diagram (ENV_ELU - Max)
KN, m, C

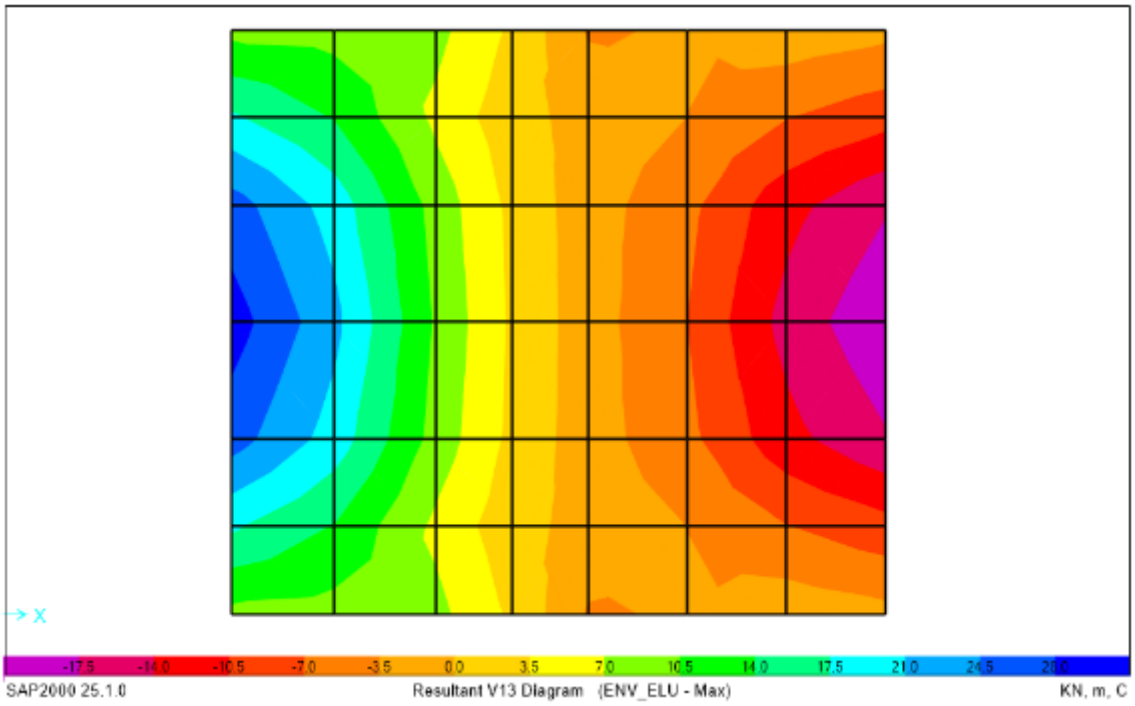

X
-84.5 -78.0 -71.5 -65.0 -58.5 -52.0 -45.5 -39.0 -32.5 -26.0 -19.5 -13.0 -6.5 0.0
SAP2000 25.1.0
Resultant F22 Diagram (ENV_ELU - Min)
KN, m, C

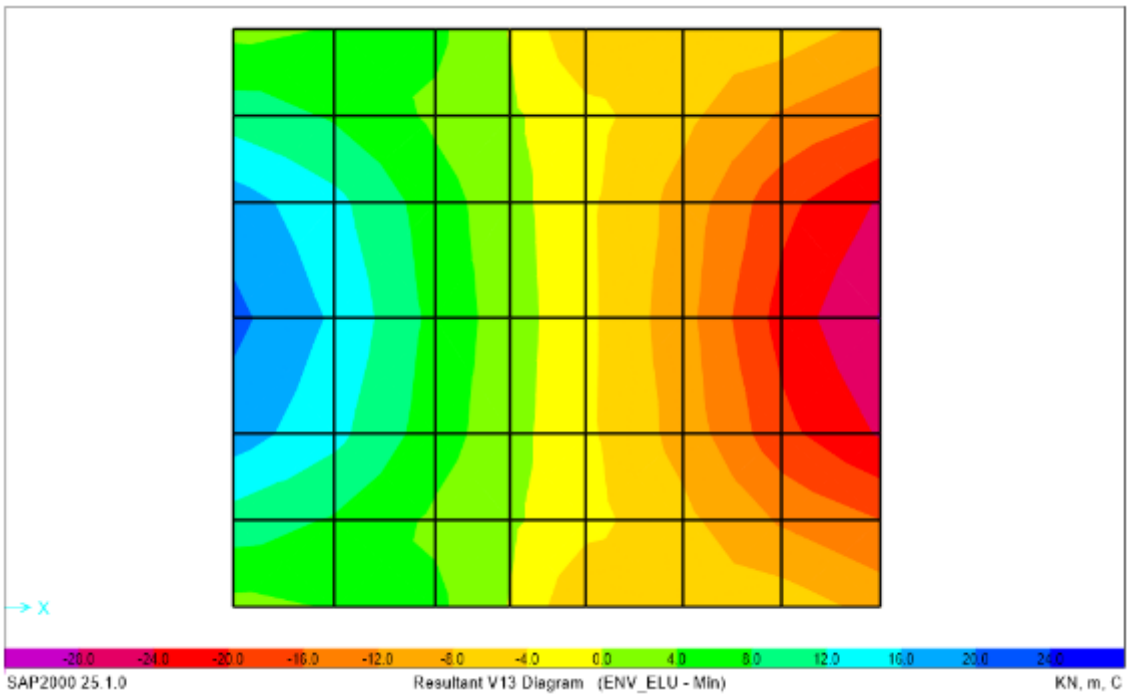

X
-7.00 -6.00 -5.00 -4.00 -3.00 -2.00 -1.00 0.00 1.00 2.00 3.00 4.00 5.00 6.00
SAP2000 25.1.0
Resultant M11 Diagram (ENV_ELU - Max)
KN, m, C

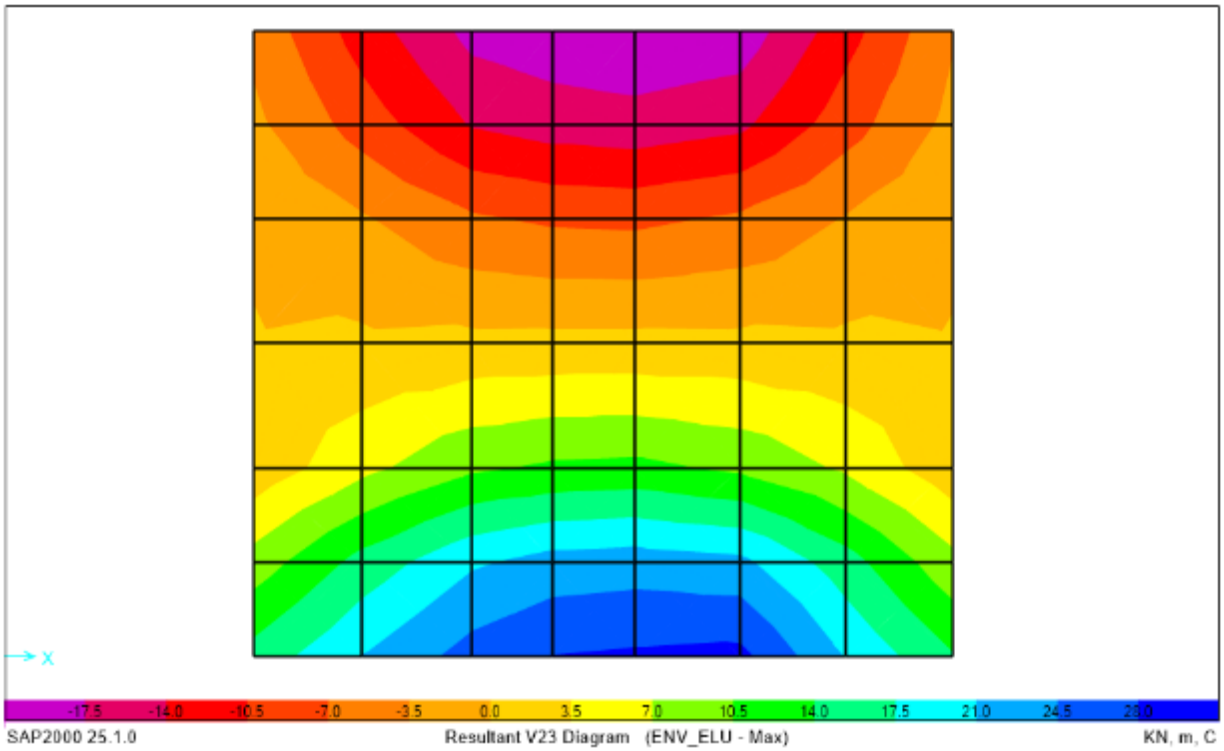

X
-14.3 -13.0 -11.7 -10.4 -9.1 -7.8 -6.5 -5.2 -3.9 -2.6 -1.3 0.0 1.3 2.6
SAP2000 25.1.0
Resultant M11 Diagram (ENV_ELU - Min)
KN, m, C

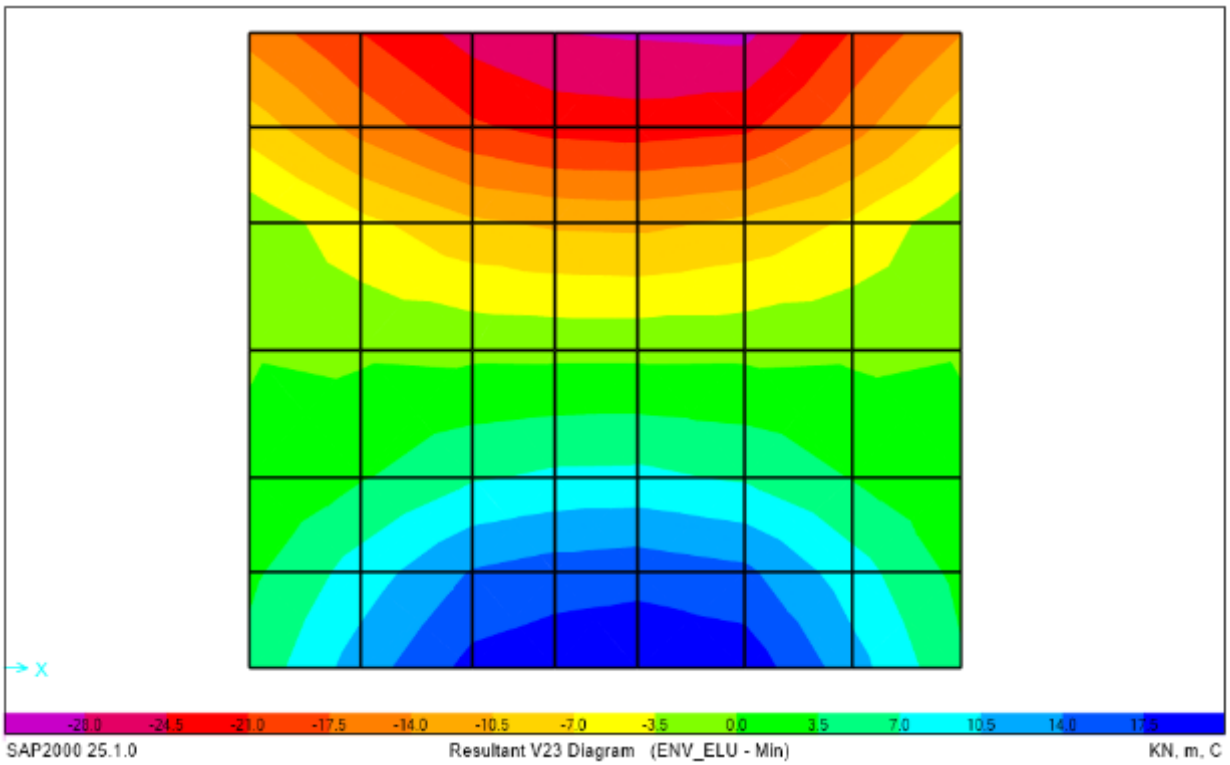

X
-7.00 -6.00 -5.00 -4.00 -3.00 -2.00 -1.00 0.00 1.00 2.00 3.00 4.00 5.00 6.00
SAP2000 25.1.0
Resultant M22 Diagram (ENV_ELU - Max)
KN, m, C


X
-15.6 -14.3 -13.0 -11.7 -10.4 -9.1 -7.8 -6.5 -5.2 -3.9 -2.6 -1.3 0.0 1.3
SAP2000 25.1.0
Resultant M22 Diagram (ENV_ELU - Min)
KN, m, C


X
-17.5 -14.0 -10.5 -7.0 -3.5 0.0 3.5 7.0 10.5 14.0 17.5 21.0 24.5 28.0
SAP2000 25.1.0
Resultant V13 Diagram (ENV_ELU - Max)
KN, m, C

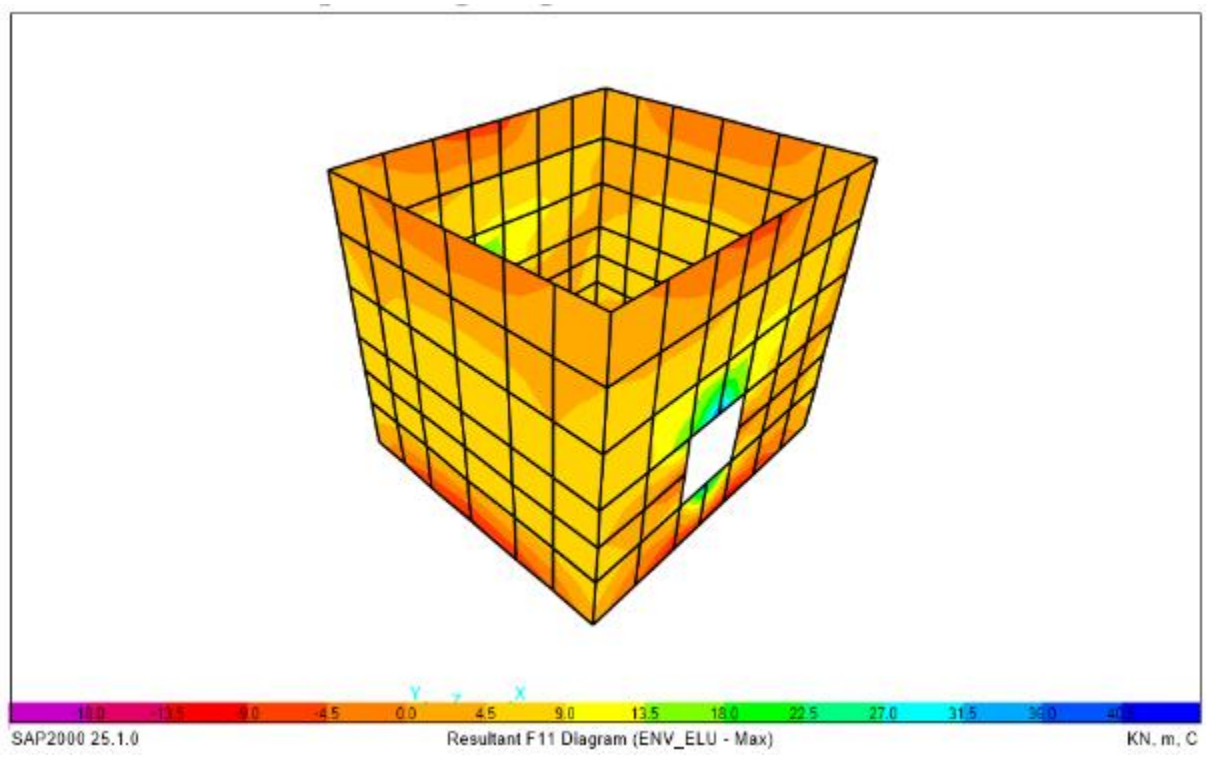

X
-28.0 -24.0 -20.0 -16.0 -12.0 -8.0 -4.0 0.0 4.0 8.0 12.0 16.0 20.0 24.0
SAP2000 25.1.0
Resultant V13 Diagram (ENV_ELU - Min)
KN, m, C

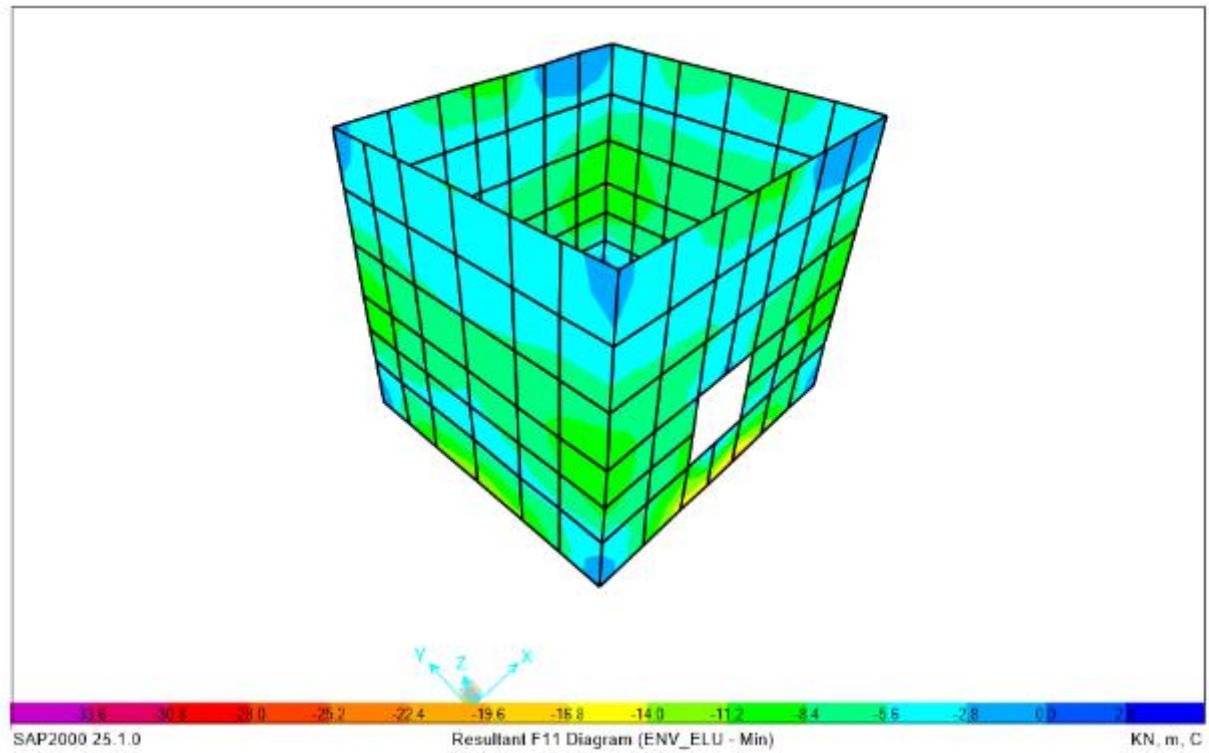

X
-17.5 -14.0 -10.5 -7.0 -3.5 0.0 3.5 7.0 10.5 14.0 17.5 21.0 24.5 28.0
SAP2000 25.1.0
Resultant V23 Diagram (ENV_ELU - Max)
KN, m, C

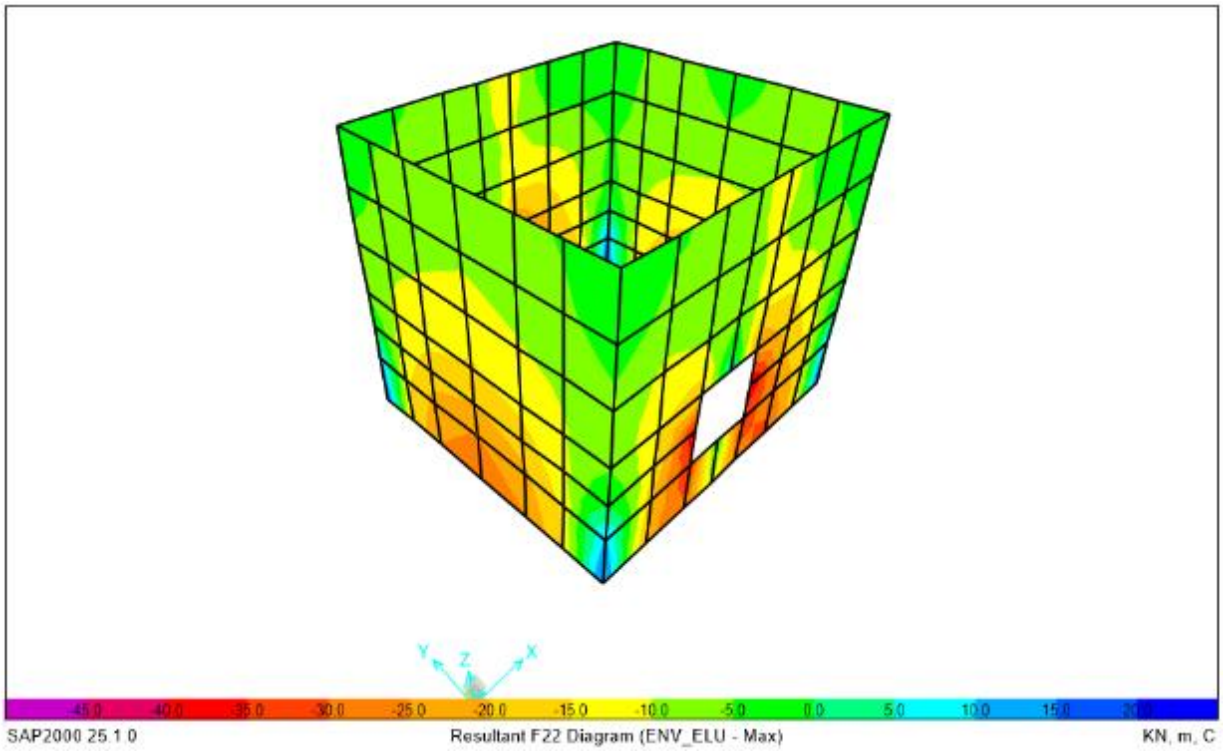

X
-28.0 -24.5 -21.0 -17.5 -14.0 -10.5 -7.0 -3.5 0.0 3.5 7.0 10.5 14.0 17.5
SAP2000 25.1.0
Resultant V23 Diagram (ENV_ELU - Min)
KN, m, C

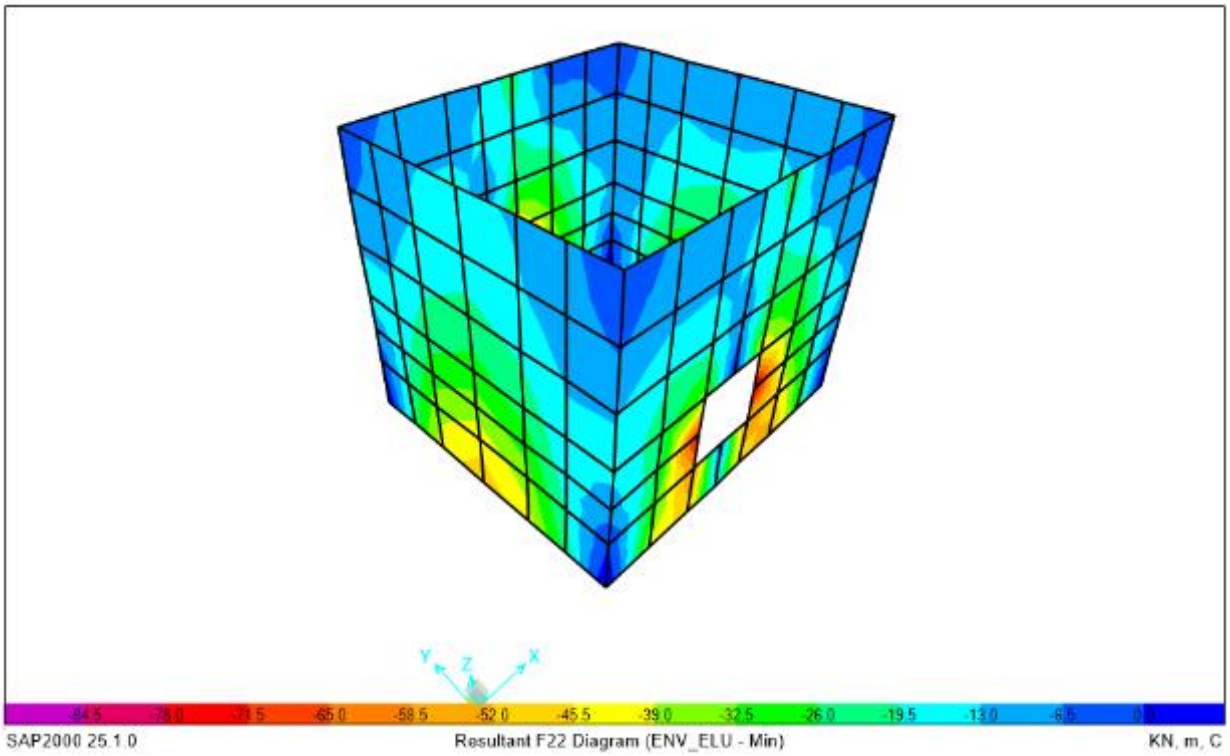
**Muros**

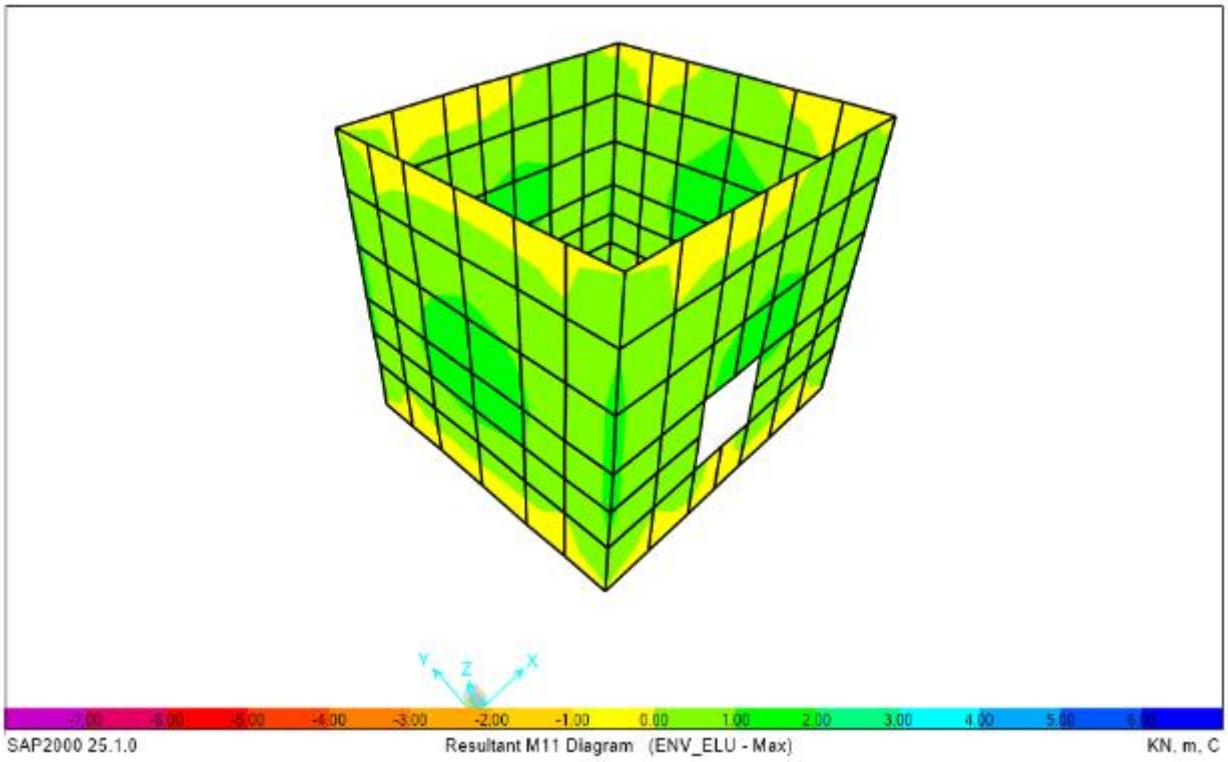
| MUROS – LRFD RESULTADOS | | | | | |
|---|---|---|---|---|---|
| | **$F_{11}$ (kN)** | **$M_{11}$ (kNm)** | **$F_{22}$ (kN)** | **$M_{22}$ (kNm)** | **Vmax (kN)** |
| **ELU (min)** | -24,31 | -3,36 | -89,33 | -6,43 | 0,1 |
| **ELU (max)** | 38,98 | 1,84 | 18,03 | 3,21 | 14,11 |

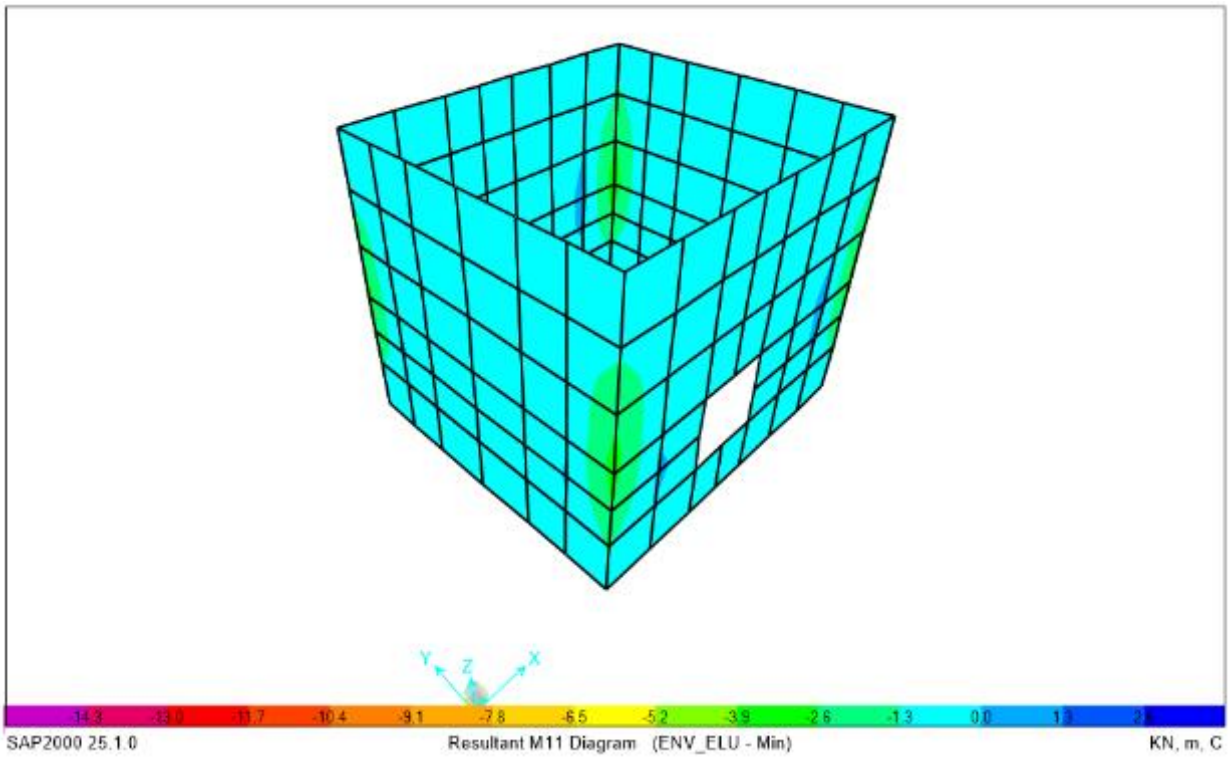


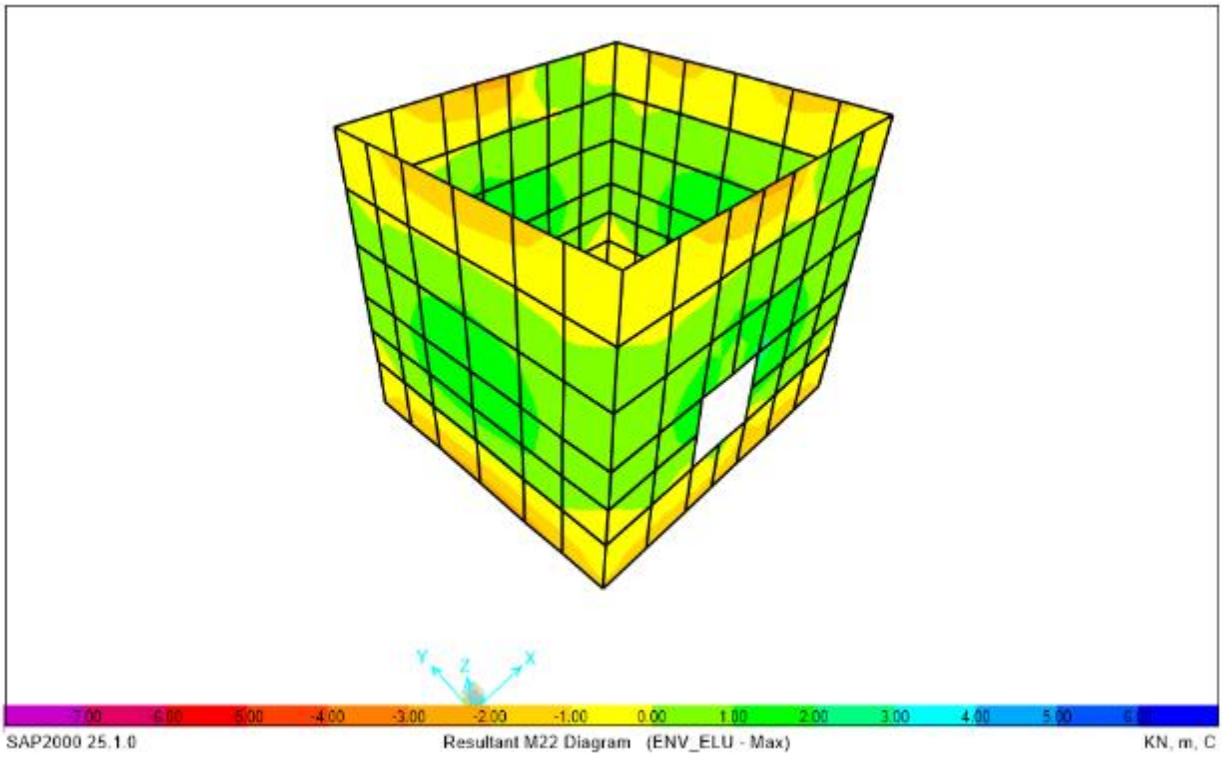



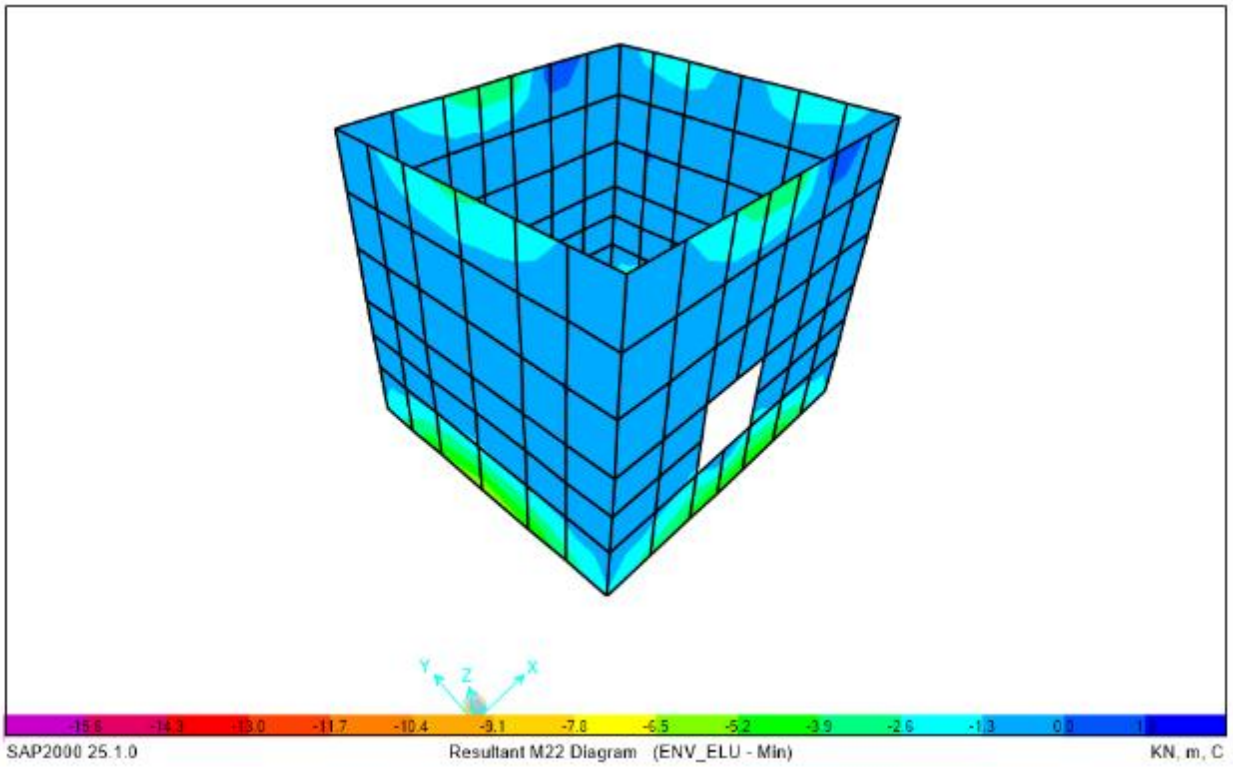

Y
Z
X
-45.0
-40.0
-35.0
-30.0
-25.0
-20.0
-15.0
-10.0
-5.0
0.0
5.0
10.0
15.0
20.0
SAP2000 25.1.0
Resultant F22 Diagram (ENV_ELU - Max)
KN, m, C

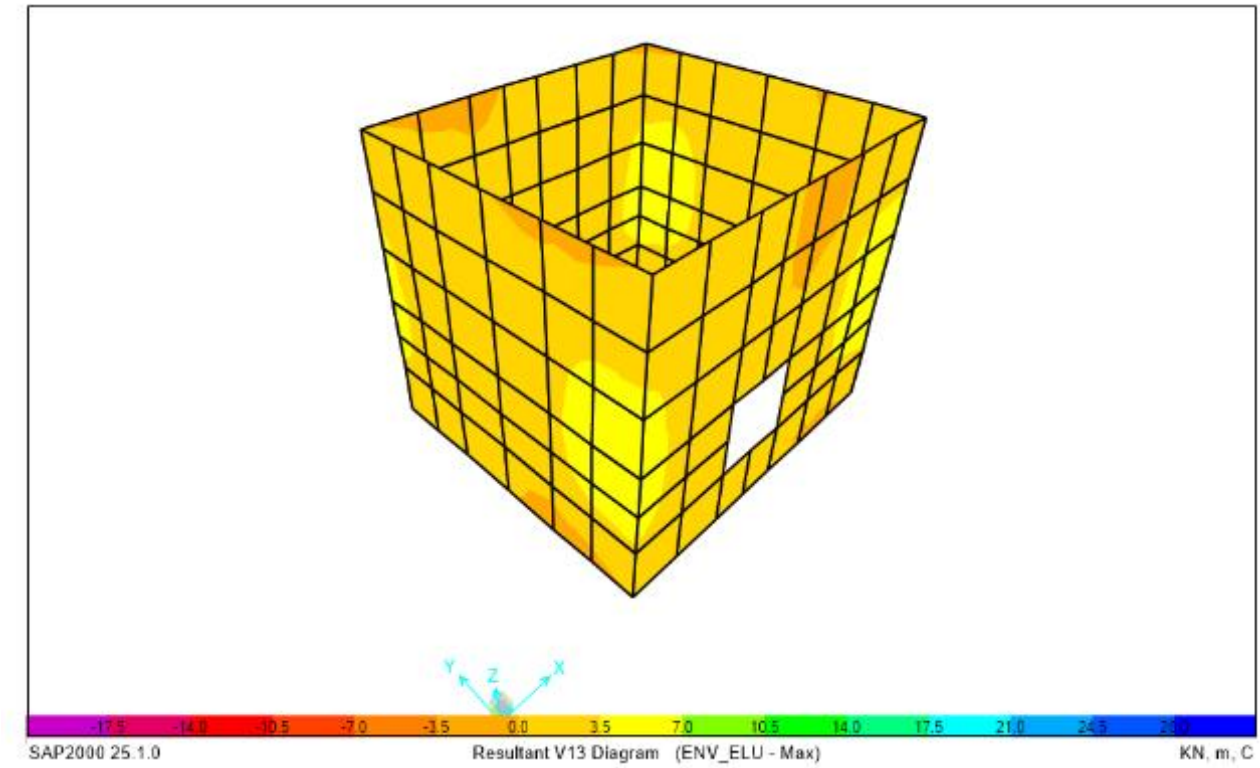

Y
Z
X
-84.5
-78.0
-71.5
-65.0
-58.5
-52.0
-45.5
-39.0
-32.5
-26.0
-19.5
-13.0
-6.5
0.0
SAP2000 25.1.0
Resultant F22 Diagram (ENV_ELU - Min)
KN, m, C

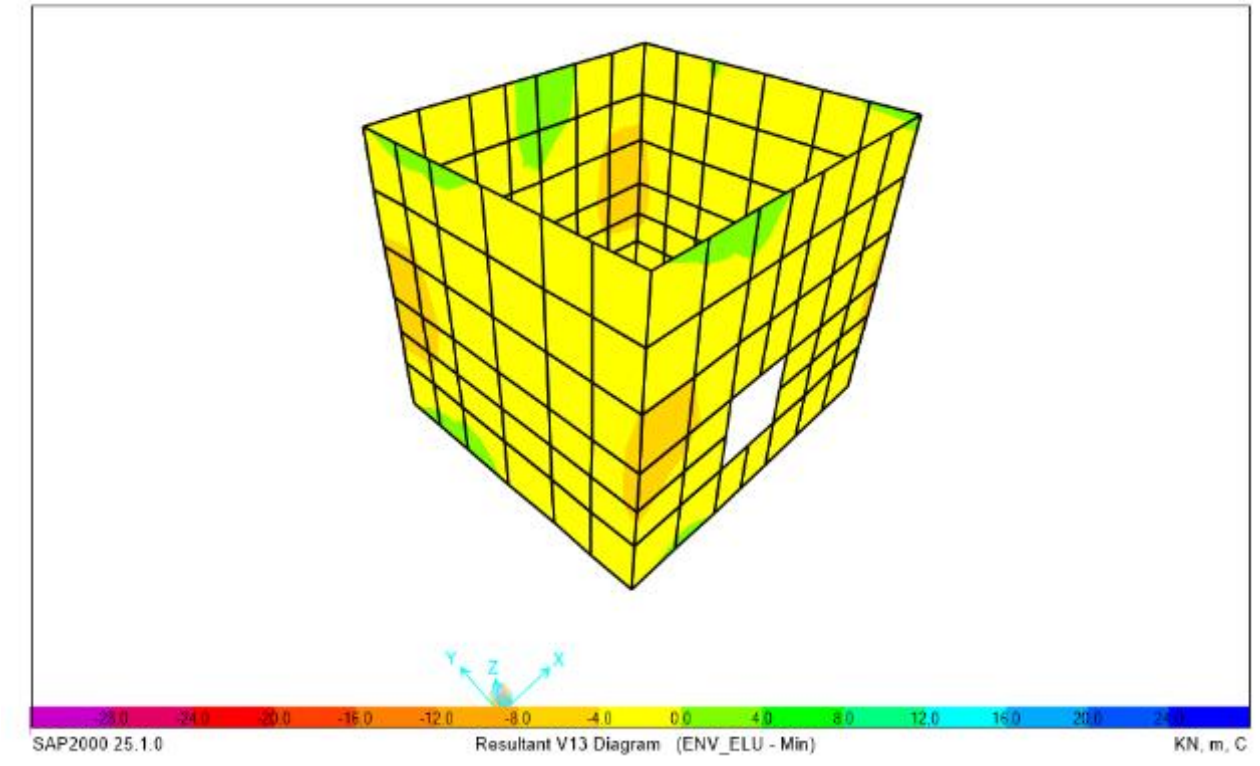

Y
Z
X
-7.00
-6.00
-5.00
-4.00
-3.00
-2.00
-1.00
0.00
1.00
2.00
3.00
4.00
5.00
SAP2000 25.1.0
Resultant M11 Diagram (ENV_ELU - Max)
KN, m, C

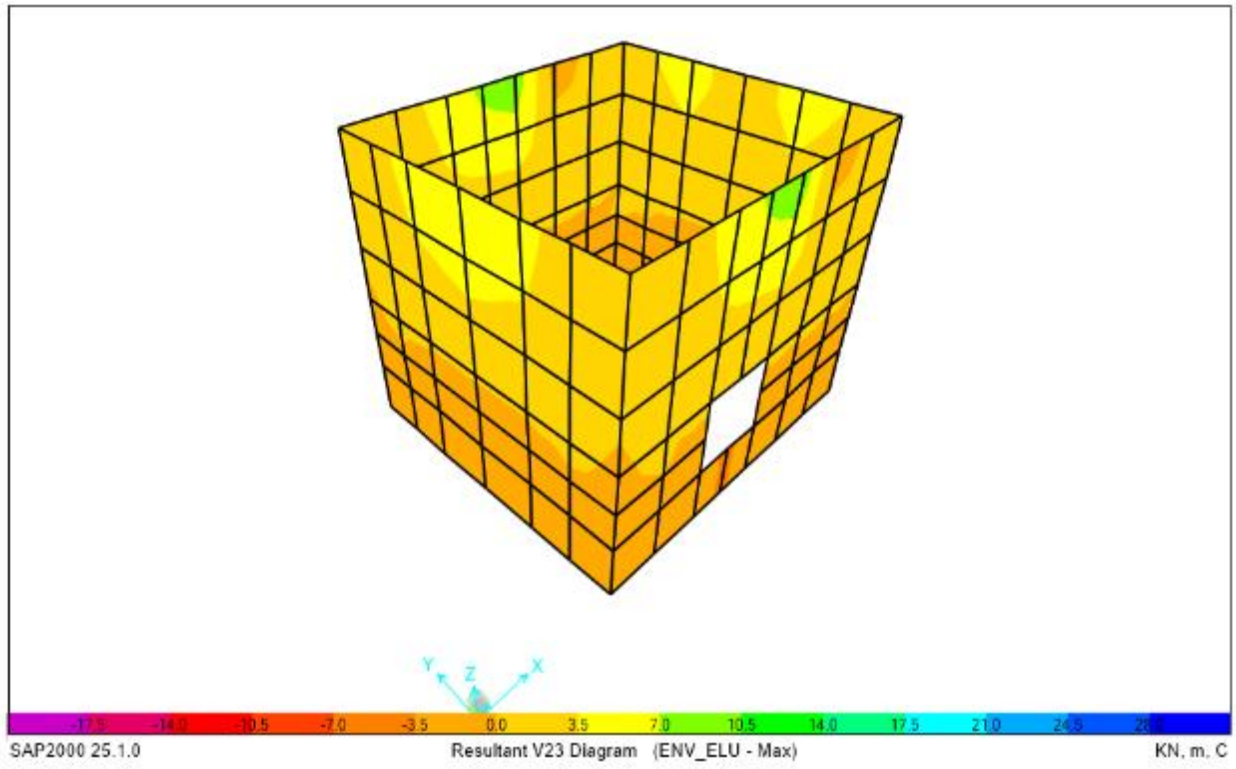

Y
Z
X
-14.3
-13.0
-11.7
-10.4
-9.1
-7.8
-6.5
-5.2
-3.9
-2.6
-1.3
0.0
1.3
SAP2000 25.1.0
Resultant M11 Diagram (ENV_ELU - Min)
KN, m, C

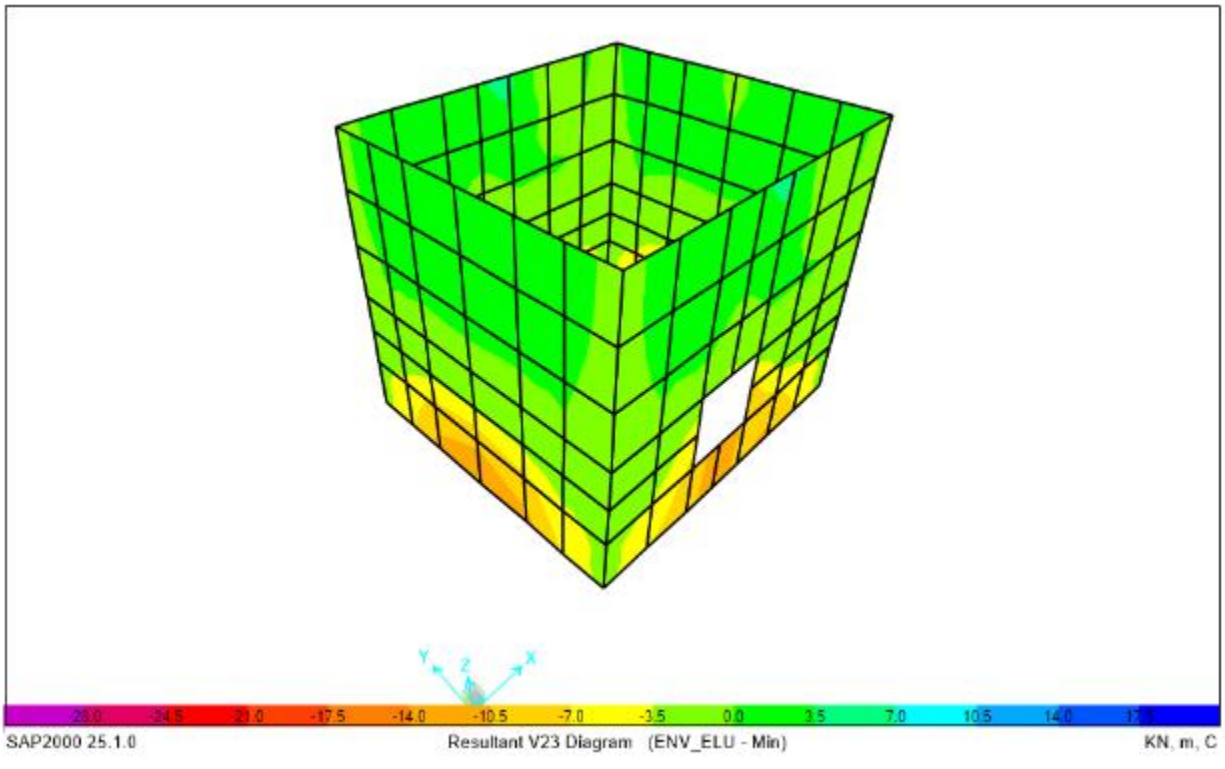

Y
Z
X
-7.00
-6.00
-5.00
-4.00
-3.00
-2.00
-1.00
0.00
1.00
2.00
3.00
4.00
5.00
SAP2000 25.1.0
Resultant M22 Diagram (ENV_ELU - Max)
KN, m, C


Y
Z
X
-15.6
-14.3
-13.0
-11.7
-10.4
-9.1
-7.8
-6.5
-5.2
-3.9
-2.6
-1.3
0.0
SAP2000 25.1.0
Resultant M22 Diagram (ENV_ELU - Min)
KN, m, C


Y
Z
X
-17.5 -14.0 -10.5 -7.0 -3.5 0.0 3.5 7.0 10.5 14.0 17.5 21.0 24.5
SAP2000 25.1.0
Resultant V13 Diagram (ENV_ELU - Max)
KN, m, C

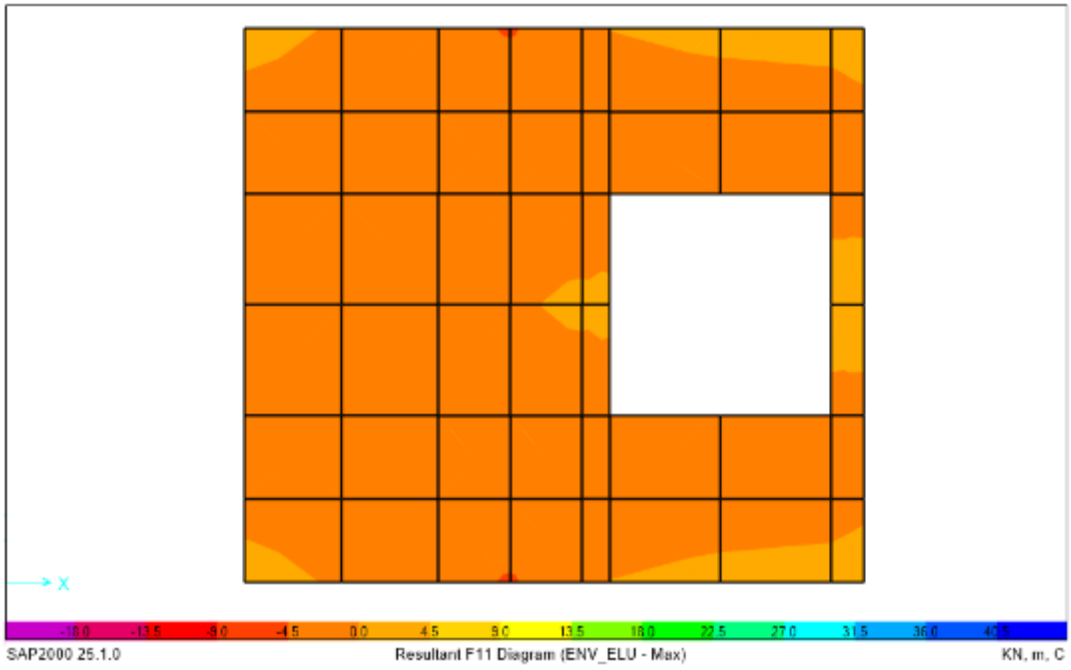

Y
Z
X
-28.0 -24.0 -20.0 -16.0 -12.0 -8.0 -4.0 0.0 4.0 8.0 12.0 16.0 20.0 24.0
SAP2000 25.1.0
Resultant V13 Diagram (ENV_ELU - Min)
KN, m, C

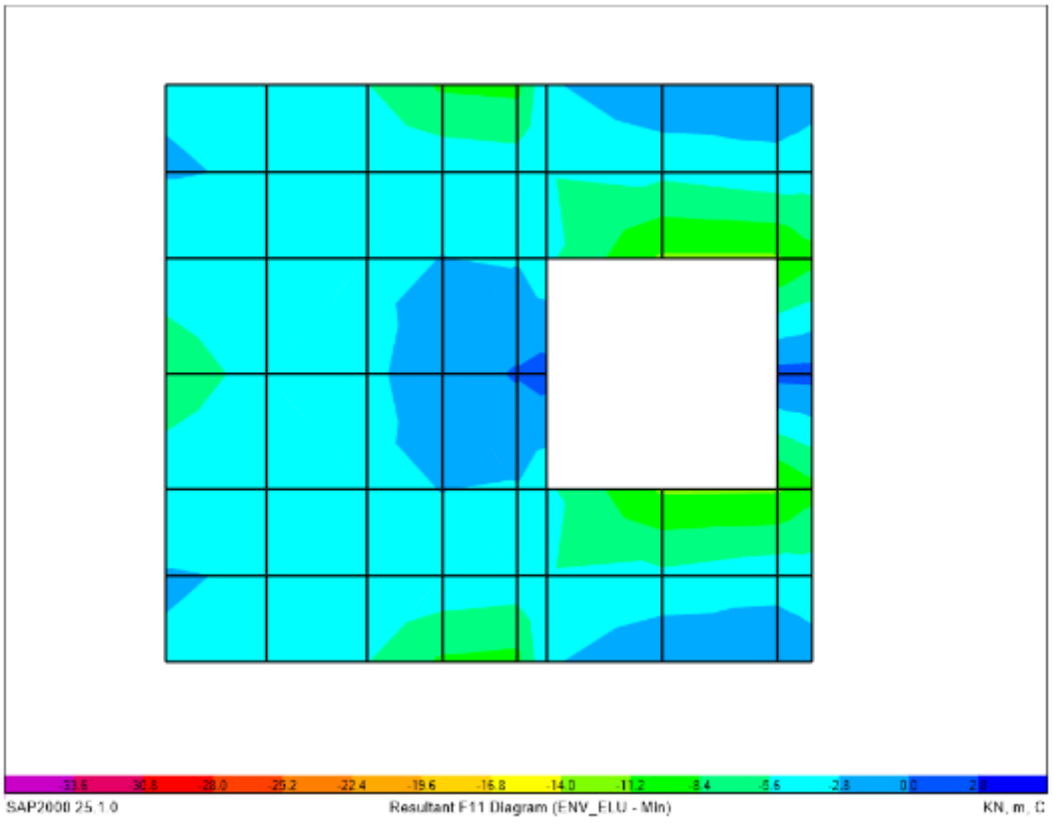

Y
Z
X
-17.5
-14.0
-10.5
-7.0
-3.5
0.0
3.5
7.0
10.5
14.0
17.5
21.0
24.5
SAP2000 25.1.0
Resultant V23 Diagram (ENV_ELU - Max)
KN, m, C

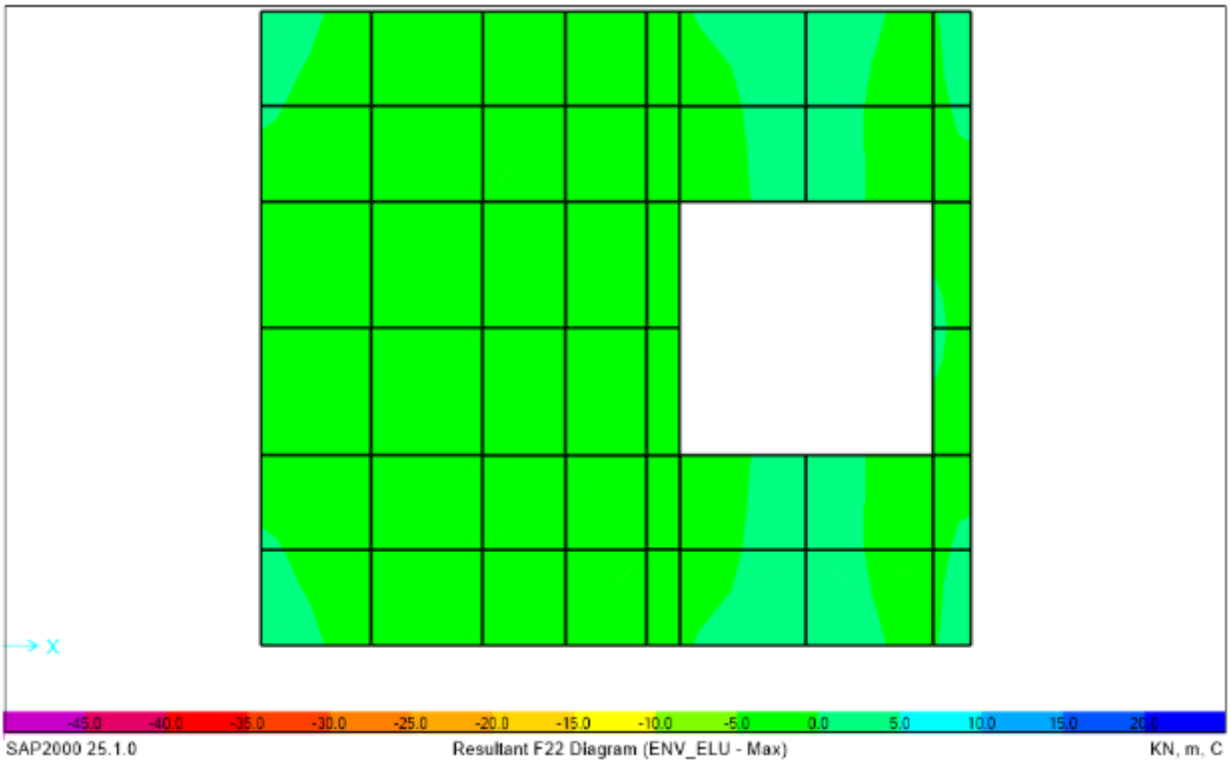

Y
Z
X
-28.0
-24.5
-21.0
-17.5
-14.0
-10.5
-7.0
-3.5
0.0
3.5
7.0
10.5
14.0
SAP2000 25.1.0
Resultant V23 Diagram (ENV_ELU - Min)
KN, m, C

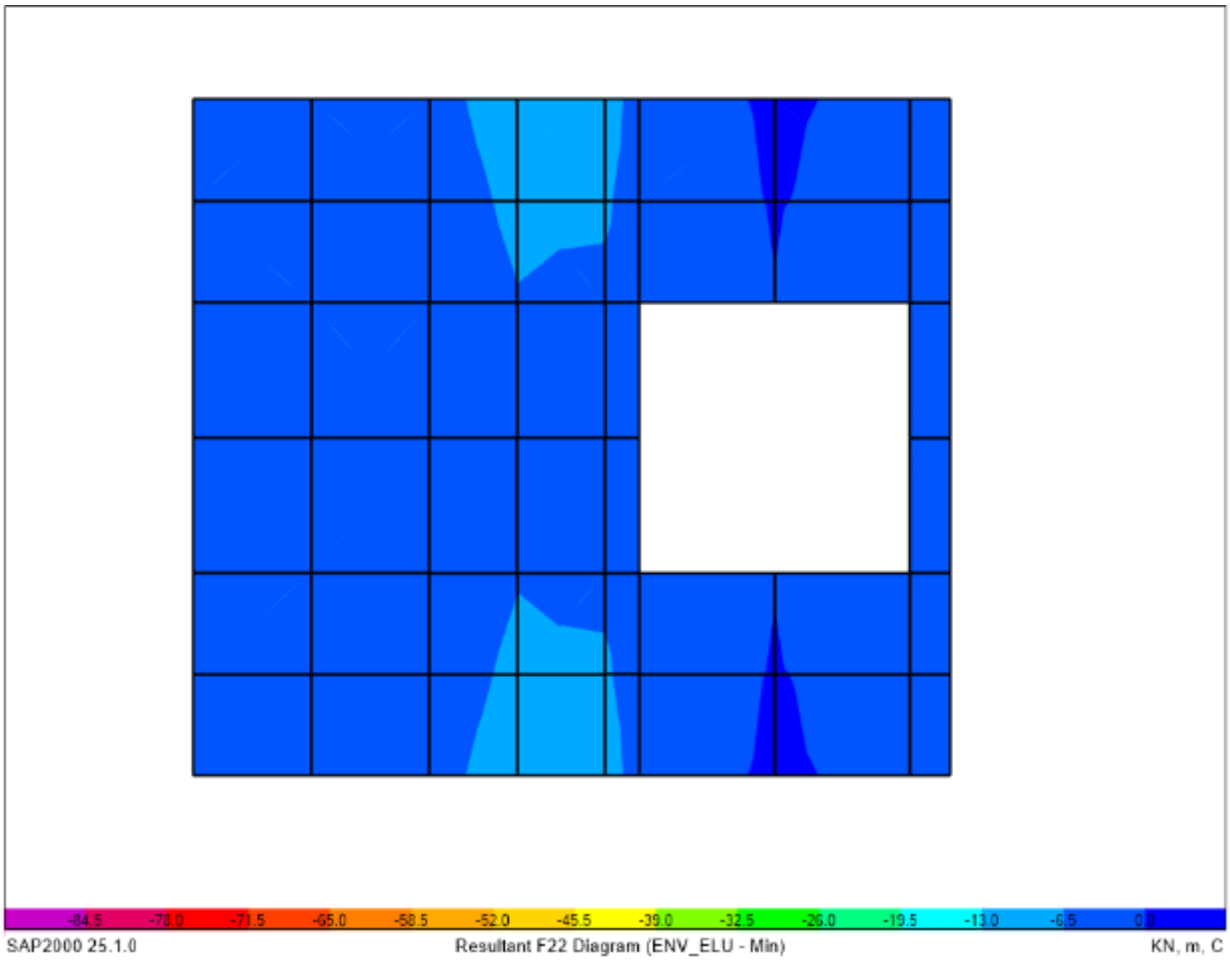
**Losa superior**

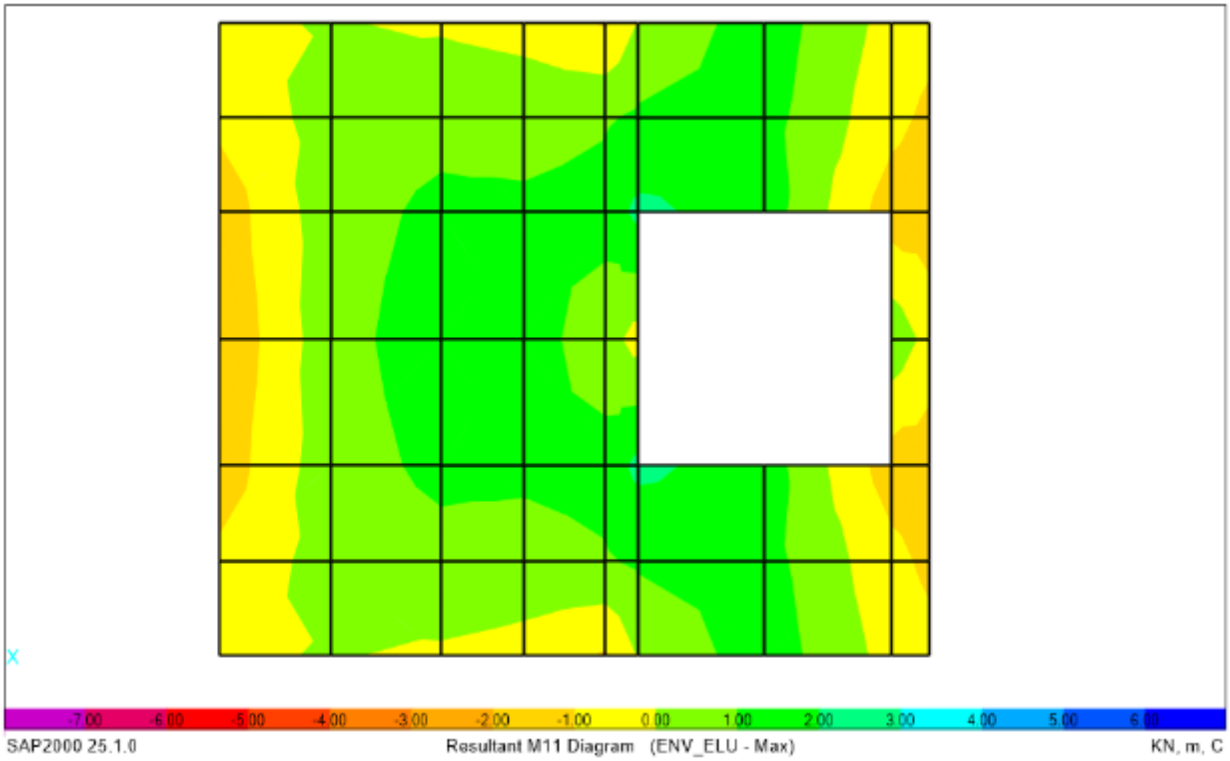
| LOSA SUPERIOR - LRFD RESULTADOS | | | | | |
|---|---|---|---|---|---|
| | $F_{11}$ (kN) | $M_{11}$ (kNm) | $F_{22}$ (kN) | $M_{22}$ (kNm) | Vmax (kN) |
| **ELU (min)** | -16,77 | -3,32 | -11,94 | -5,97 | 0,19 |
| **ELU (max)** | 3,69 | 3,34 | 3,15 | 3,35 | 29,65 |

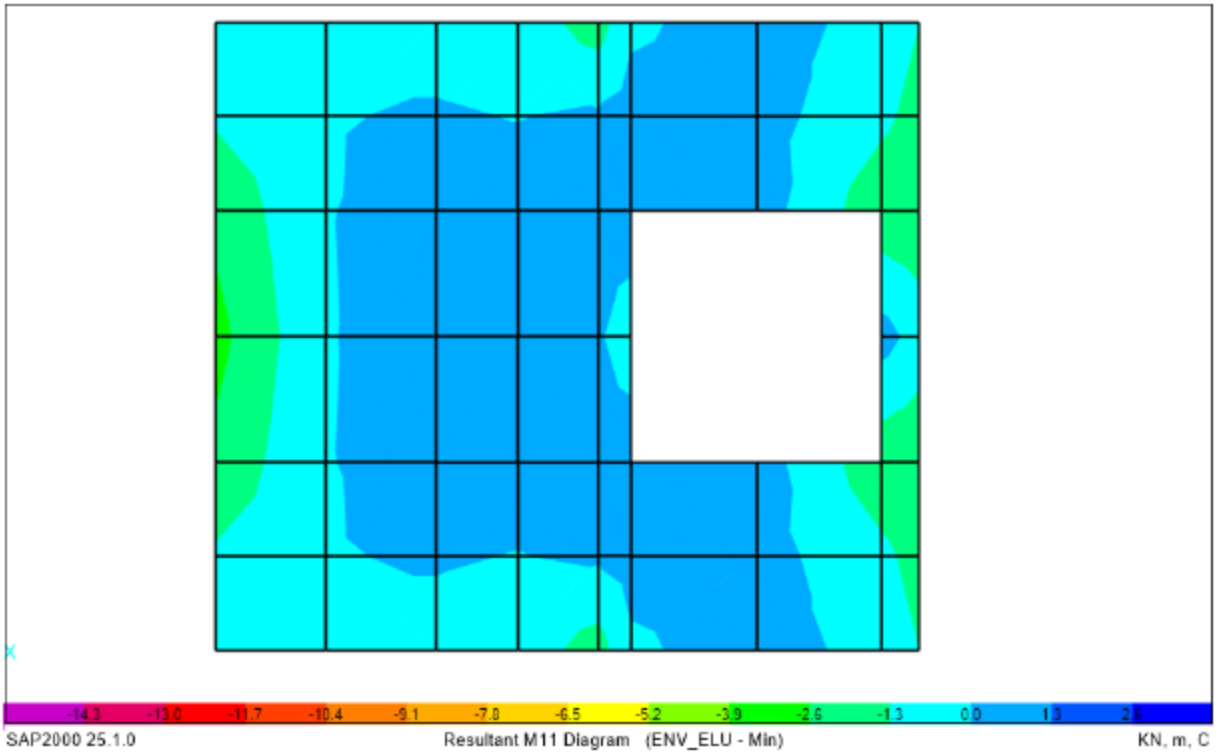


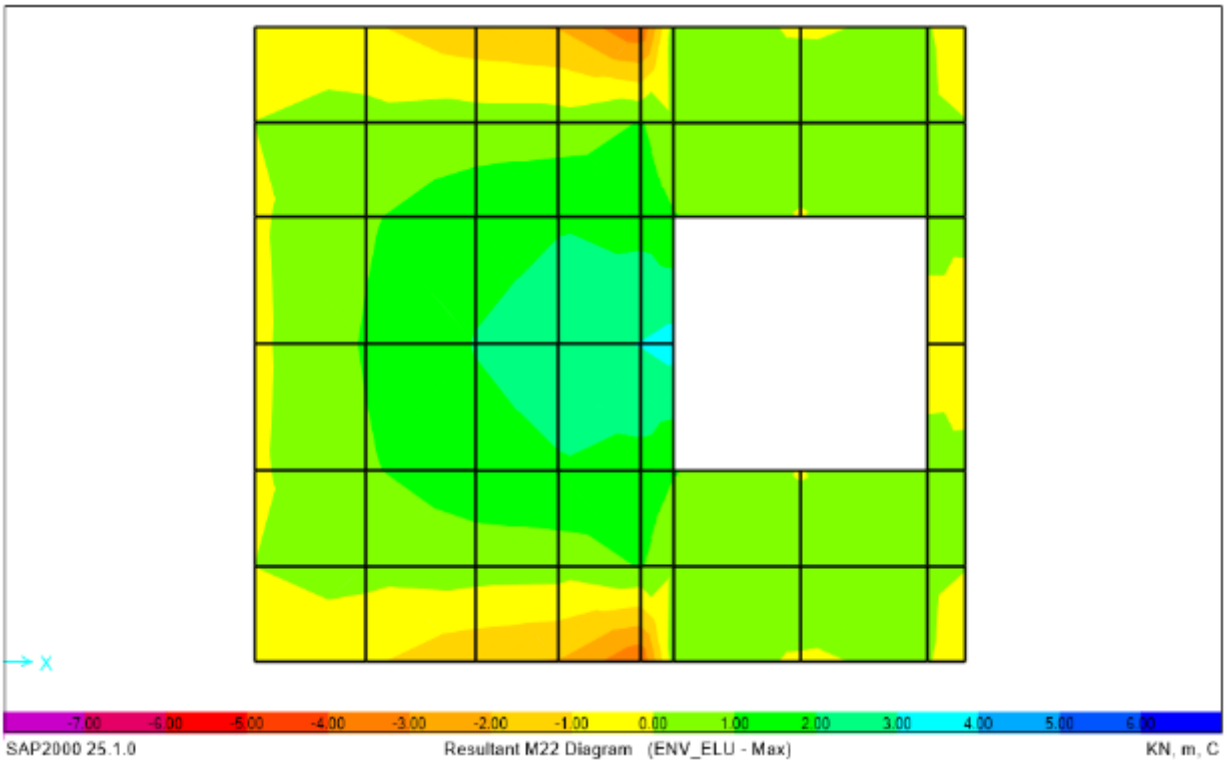



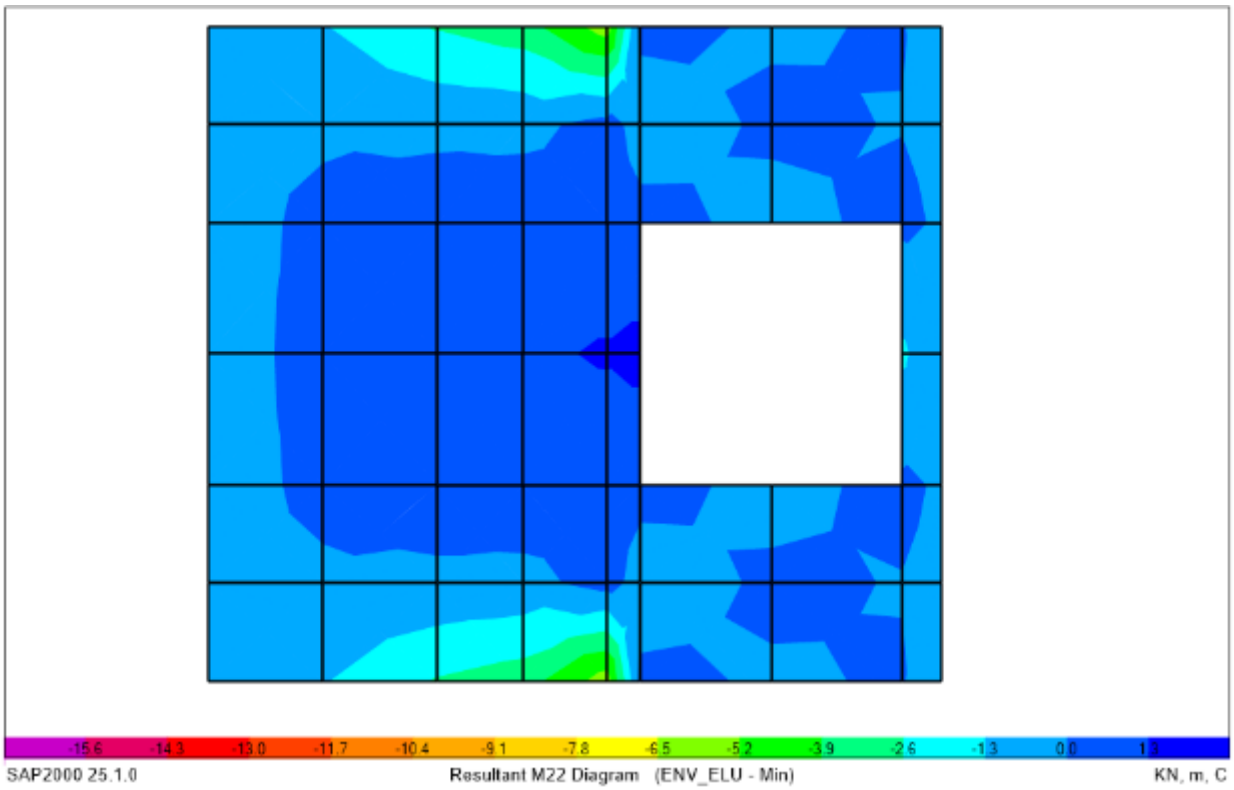

X
-45.0 -40.0 -35.0 -30.0 -25.0 -20.0 -15.0 -10.0 -5.0 0.0 5.0 10.0 15.0 20.0
SAP2000 25.1.0
Resultant F22 Diagram (ENV_ELU - Max)
KN, m, C

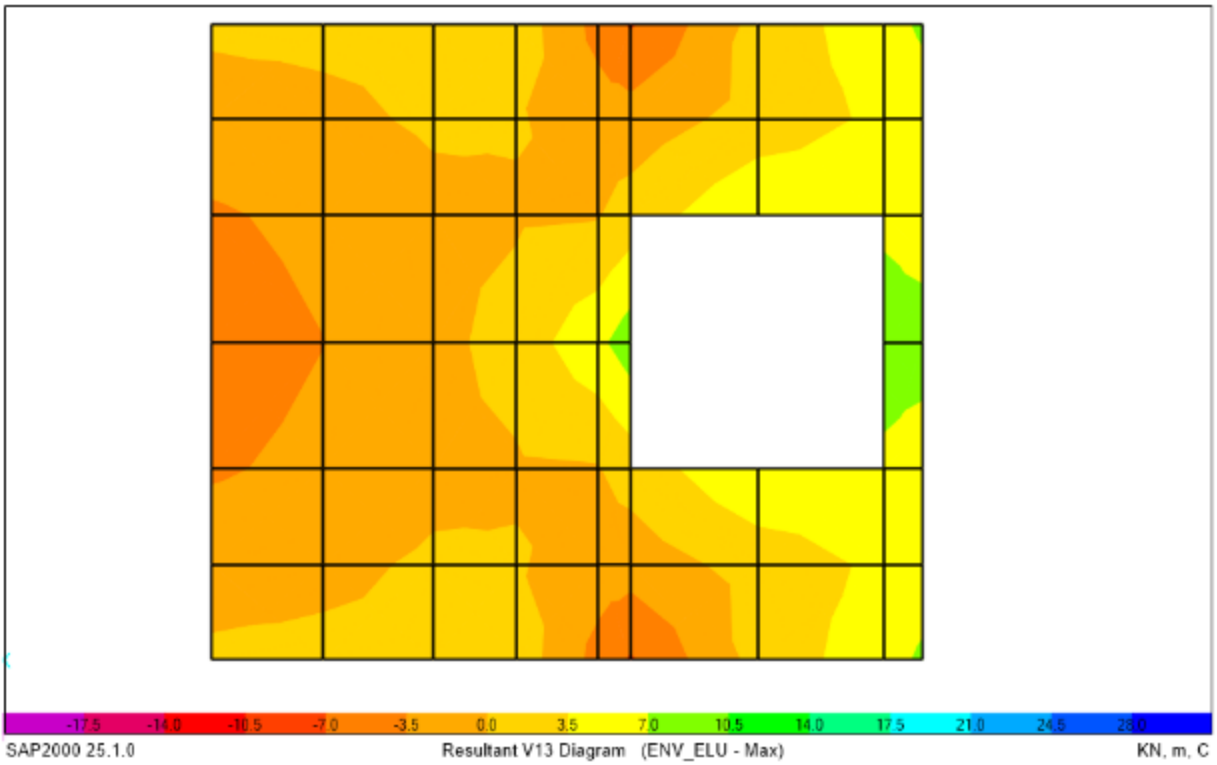

-84.5 -78.0 -71.5 -65.0 -58.5 -52.0 -45.5 -39.0 -32.5 -26.0 -19.5 -13.0 -6.5 0.0
SAP2000 25.1.0
Resultant F22 Diagram (ENV_ELU - Min)
KN, m, C

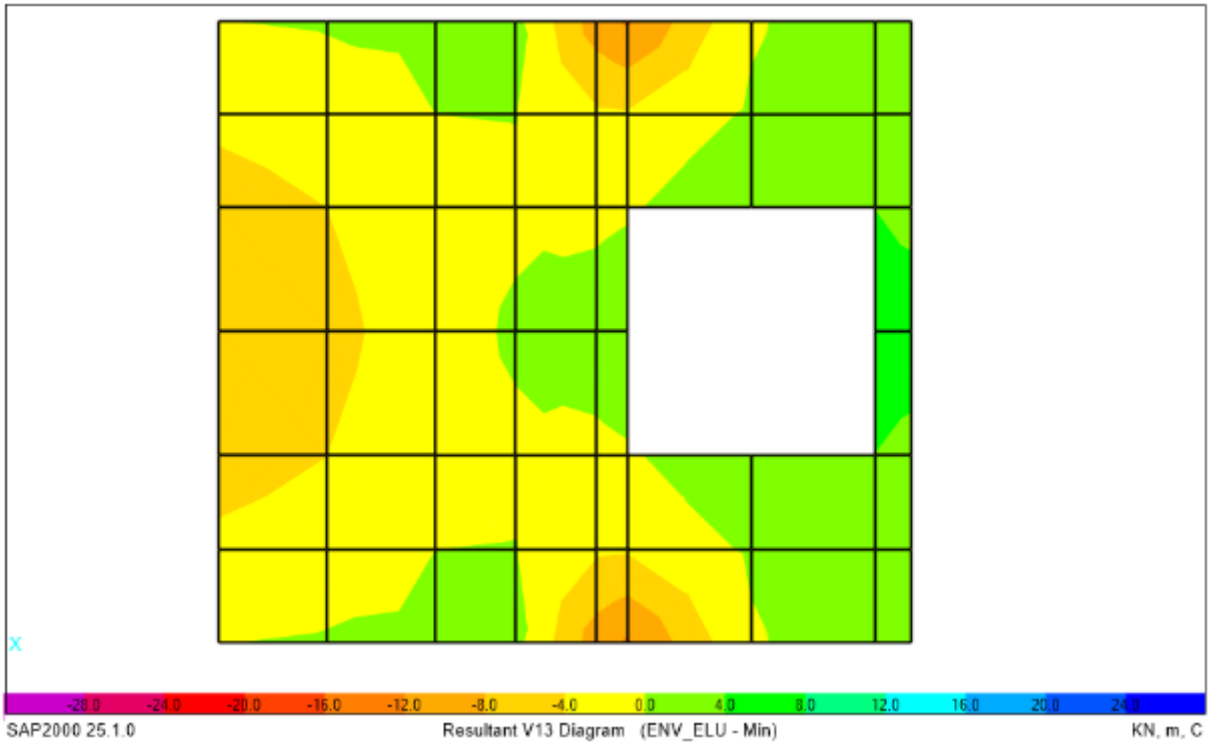

-7.00 -6.00 -5.00 -4.00 -3.00 -2.00 -1.00 0.00 1.00 2.00 3.00 4.00 5.00 6.00
SAP2000 25.1.0
Resultant M11 Diagram (ENV_ELU - Max)
KN, m, C

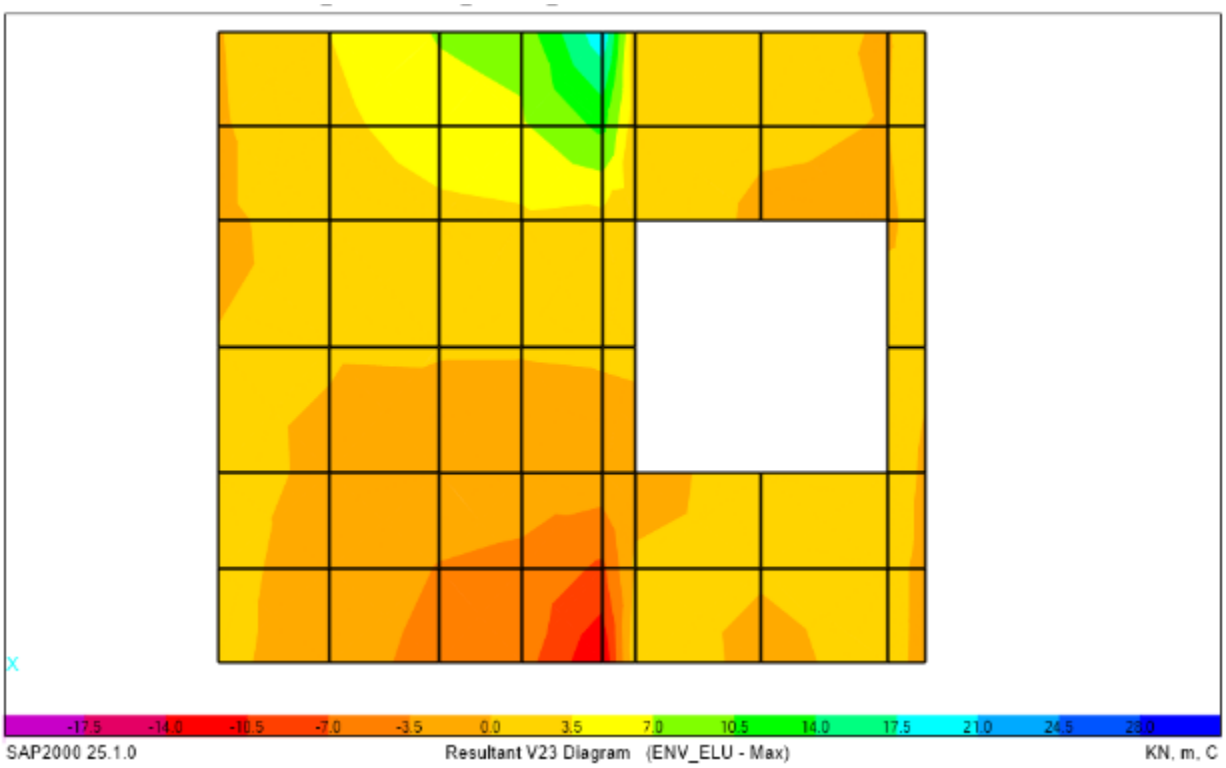

-14.3 -13.0 -11.7 -10.4 -9.1 -7.8 -6.5 -5.2 -3.9 -2.6 -1.3 0.0 1.3 2.6
SAP2000 25.1.0
Resultant M11 Diagram (ENV_ELU - Min)
KN, m, C

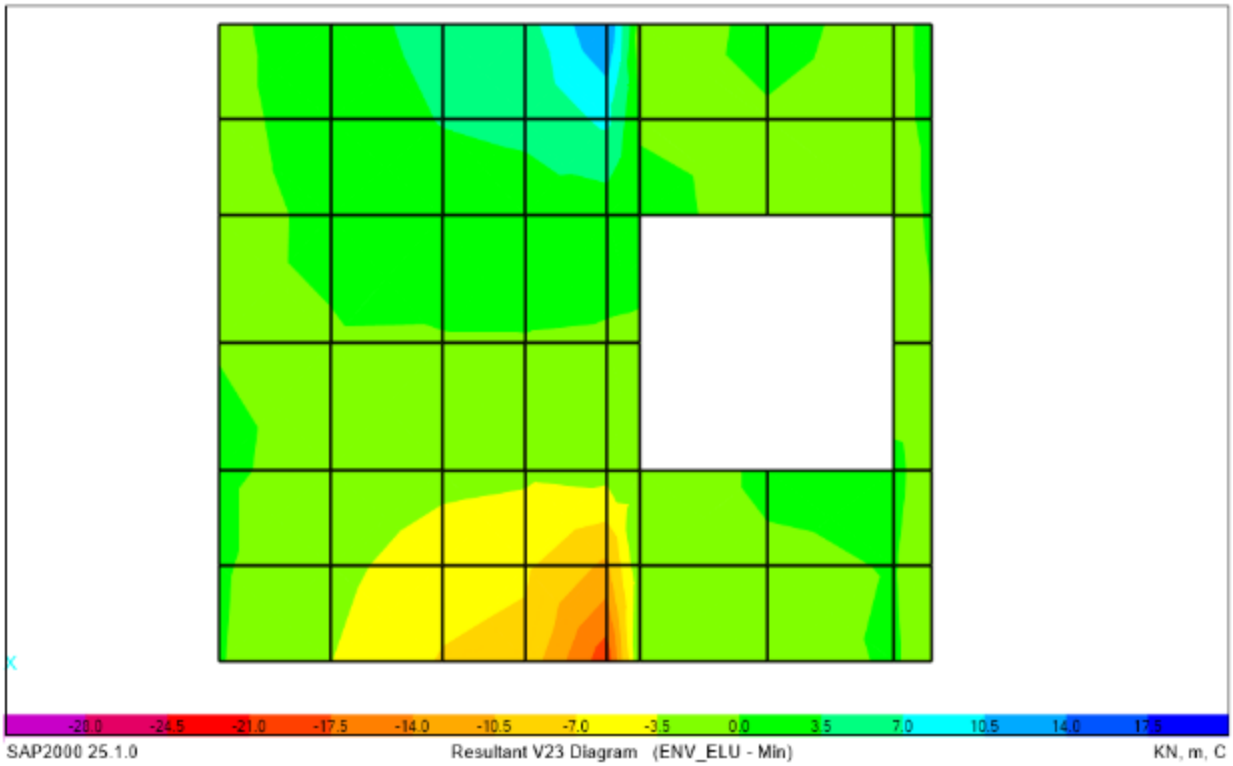

X
-7.00 -6.00 -5.00 -4.00 -3.00 -2.00 -1.00 0.00 1.00 2.00 3.00 4.00 5.00 6.00
SAP2000 25.1.0
Resultant M22 Diagram (ENV_ELU - Max)
KN, m, C


-15.6 -14.3 -13.0 -11.7 -10.4 -9.1 -7.8 -6.5 -5.2 -3.9 -2.6 -1.3 0.0 1.3
SAP2000 25.1.0
Resultant M22 Diagram (ENV_ELU - Min)
KN, m, C


-17.5 -14.0 -10.5 -7.0 -3.5 0.0 3.5 7.0 10.5 14.0 17.5 21.0 24.5 28.0
SAP2000 25.1.0
Resultant V13 Diagram (ENV_ELU - Max)
KN, m, C


-28.0 -24.0 -20.0 -16.0 -12.0 -8.0 -4.0 0.0 4.0 8.0 12.0 16.0 20.0 24.0
SAP2000 25.1.0
Resultant V13 Diagram (ENV_ELU - Min)
KN, m, C


-17.5 -14.0 -10.5 -7.0 -3.5 0.0 3.5 7.0 10.5 14.0 17.5 21.0 24.5 28.0
SAP2000 25.1.0
Resultant V23 Diagram (ENV_ELU - Max)
KN, m, C


-28.0 -24.5 -21.0 -17.5 -14.0 -10.5 -7.0 -3.5 0.0 3.5 7.0 10.5 14.0 17.5
SAP2000 25.1.0
Resultant V23 Diagram (ENV_ELU - Min)
KN, m, C

### 3.8.4 Verificaciones Estado Límite Último (ELU)

**Losa base inferior**

Se propone el siguiente armado:

| ARMADO LOSA BASE INFERIOR | | |
|---|---|---|
| Armadura longitudinal/transversal (cara superior) | Armadura longitudinal/transversal (cara inferior) | Armadura de cortante |
| Ø16@200mm (10.05cm$^2$/m) | Ø16@200mm (10.05cm$^2$/m) | No requerida |

| FLEXURE REINFORCEMENT CALCULATION | | |
|---|---|---|
| REF: EN-1992-1-1 | | |
| **Section inputs & material** | | |
| Flexure design moment | $M_d$ (KNm) | 16 |
| Section width | b (mm) | 1000 |
| Section heigth | h(mm) | 600 |
| Minimum cover | r (mm) | 50 |
| Effective section heigth | d (mm) | 542 |
| Specified compressive strength of concrete | $f_{ck}$(N/mm$^2$) | 25 |
| Coeff. for long term effects in compressive strength (chapter 3.1.6 EN-1992-1-1) | $a_{cc}$ | 0.85 |
| Partial factor for concrete, table 2.1N | $\gamma_c$ | 1.5 |
| Design value of concrete compressive strength $f_{cd} = \alpha_{cc} f_{ck} / \gamma_C$ | $f_{cd}$ (N/mm$^2$) | 14.17 |
| Mean tensile strength (according to table 3.1 EN 1992-1-1) | $f_{ctm}$ (N/mm$^2$) | 2.6 |
| Specified yield strength of reinforcement | $f_{yk}$ (N/mm$^2$) | 500 |
| Partial factor for reinforcing, table 2.1N | $\gamma_s$ | 1.15 |
| Design yield strength of reinforcement | $f_{yd}$ (N/mm$^2$) | 435 |
| Modulus of elasticity of reinforcement | $E_s$ (N/mm$^2$) | 200000 |
| for $f_{ck}$ < 50MPa (3.19) | l | 0.8 |
| for $f_{ck}$ < 50MPa (3.21) | h | 1.00 |
| | $k_1$ | 0.44 |
| | $k_2$ | 1.25 |
| (for $f_{ck}$ < 50MPa )Ultimate concrete strain (table 3.1) | $e_{cu2}$ | 0.0035 |
| Ratio of the redistributed moment to the elastic bending moment | d | 1.00 |
| | $(x/d)_{lim}$ | 0.45 |
| Strain in concrete, max value (table 3.1) | $\varepsilon_c$ (max) | 0.0035 |
| Strain in concrete, min value (table 3.1) | $\varepsilon_c$ (min) | 0.00175 |
| Normalized moment | m | 0.0038 |
| Normalized section capacity as a singly reinforced beam | $m_{lim}$ | 0.2942 |
| | $x_{lim}$(mm) | 242.8160 |
| **Reinforcement** | | |
| | If m<$m_{lim}$: | **APPLIED** |
| Normalized steel ratio | w | 0.00385 |
| Longitudinal reinforcement area in tensile | $A_s$ (cm$^2$) | 0.680 |
| | If m>$m_{lim}$: | **NOT APPLIED** |
| | $w_{lim}$ | 0.3584 |
| Depth to the compression steel, measured from the concrete compression face | d´ (mm) | 58 |
| | w´ | -0.32512172 |
| | w | 0.03327828 |
| Stress in the compression steel | $f_s$´ (N/mm$^2$) | 434.7826087 |
| Longitudinal reinforcement area in compression | $A_s$´(cm$^2$) (up for $M_d$+) | Not required |
| Longitudinal reinforcement area in tensile | $A_s$ (cm$^2$) (bottom for $M_d$+) | 5.88 |

| | | |
|---|---|---|
| OVERALL Required Md | $A_s'$ ($cm^2$) (up for $M_d$ +) | 0.000 |
| OVERALL Required Md | $A_s$ ($cm^2$)(bottom for $M_d$ +) | 0.680 |
| The tensile is in both faces | T (kN) | 5.6 |
| Shear effort (6.2.3 (7), EN-1992-1-1) | $V_E$ (kN) | 0 |
| Reinf. in each face | $A_s$ ($cm^2$) | 0.064 |
| Total necessary reinf. In top face | $A_s$ ($cm^2$)(TOTAL) | **0.06** |
| Total necessary reinf. In low face (tensile face) | $A_s$ ($cm^2$)(TOTAL) | **0.74** |

**Disposed reinforcement:**

| | | |
|---|---|---|
| Diameter of bar | ϕ (mm) | 16 |
| Bar spacing | s (m) | 200 |
| Nº of reinf.layers | n | 1 |
| Area provided | A ($cm^2$) | 10.053 |
| | additional reinforcement | |
| Diameter of bar | ϕ (mm) | 0 |
| Bar spacing | s (m) | 200 |
| Area provided | A ($cm^2$) | 0.000 |
| | $A_{total}$ ($cm^2$) | 10.053 |
| | **OK Flexure** | **7%** |
| | - | - |
| - | - | - |

**Minimum reinforcement EN-1992-1-1**

| | | |
|---|---|---|
| | Section type | SLAB/FOUNDATION |
| | minimum ratio | **0.001352** |
| Minimum reinforcement for each face | $As_{min}$ ($cm^2$) | 7.328 |
| - | - | - |
| Reinforcement provided | $A_{total}$ ($cm^2$) | **10.05** |
| | **OK Minimum reinforcement** | **73%** |

**Maximum reinforcement EN-1992-1-1**

| | | |
|---|---|---|
| | maximum ratio | **0.040** |
| | $As_{max}$ ($cm^2$) | 240 |
| | **OK maximum reinforcement** | **4%** |
| | $s_{max}$ (mm) | 400 |
| | | **OK** |

| SHEAR REINFORCEMENT CALCULATION | | | |
|---|---|---|---|
| | | | EN 1992-1 AND EN 1992-2 |
| **Geometry and materials** | | | |
| Overall depth of the cross section | $h$ | [m] | 0.60 |
| Distance from the tension fiber to the centroid of the tensile reinforcement | $d'$ | [m] | 0.05 |
| Effective depth | $d$ | [m] | 0.55 |
| Smallest width of the cross section in the tensile area | $b_w$ | [m] | 1.00 |
| Number of grouted metal ducts in the web | $N_{ducts}$ | | 0 |
| Diamenter of the duct | $\phi_{duct}$ | [mm] | 0 |
| Nominal web thickness considering the PT ducts | $b_{w,nom}$ | [m] | 1.00 |
| Characteristic compressive cylinder strength of concrete at 28 days | $f_{ck}$ | [MPa] | 25 |
| Partial factor for concrete | $\gamma_c$ | | 1.2 |
| Characteristic yield strength of shear reinforcement | $f_{ywk}$ | [MPa] | 500 |
| Partial factor for reinforcing steel | $\gamma_s$ | | 1 |
| Area of tensile reinforcement | $A_{sl}$ | [$cm^2$] | 10.05 |
| Area of concrete cross section | $A_c$ | [$m^2$] | 0.60 |
| **Forces** | | | |
| Axial force in the cross section due to loading or the acing effect of prestressing ($N_{Ed}$ > 0 for compression) | $N_{Ed}$ | [kN] | 0.0 |
| Design value of the applied shear force | $V_{Ed}$ | [kN] | 31.5 |
| **Members not requiring shear reinforcement** | | | |
| | $k$ | | 1.6 |
| | $\rho_l$ | | 0.0018 |
| | $\sigma_{cp}$ | [MPa] | 0.00 |
| | $C_{Rd,c}$ | | 0.15 |
| | $v_{min}$ | [MPa] | 0.36 |
| | $k_1$ | | 0.15 |
| Design value for the shear resistance | **$V_{Rd,c}$** | **[kN]** | **219.5** |

## Muros

Se propone el siguiente armado:

| ARMADO MUROS | | |
|---|---|---|
| Armadura longitudinal/transversal (cara externa) | Armadura longitudinal/transversal (cara interna) | Armadura de cortante |
| Ø12@200mm (5,65cm²/m) | Ø12@200mm (5,65cm²/m) | No requiere armado a cortante |

| FLEXURE REINFORCEMENT CALCULATION | | |
|---|---|---|
| REF: EN-1992-1-1 | | |
| **Section inputs & material** | | |
| Flexure design moment | $M_d$ (KNm) | 6.5 |
| Section width | b (mm) | 1000 |
| Section heigth | h(mm) | 300 |
| Minimum cover | r (mm) | 50 |
| Effective section heigth | d (mm) | 244 |
| Specified compressive strength of concrete | $f_{ck}$(N/mm²) | 25 |
| Coeff. for long term effects in compressive strength (chapter 3.1.6 EN-1992-1-1) | $a_{cc}$ | 0.85 |
| Partial factor for concrete, table 2.1N | $\gamma_c$ | 1.5 |
| Design value of concrete compressive strength $f_{cd} = \alpha_{cc} f_{ck} / \gamma_C$ | $f_{cd}$ (N/mm²) | 14.17 |
| Mean tensile strength (according to table 3.1 EN 1992-1-1) | $f_{ctm}$ (N/mm²) | 2.6 |
| Specified yield strength of reinforcement | $f_{yk}$ (N/mm²) | 500 |
| Partial factor for reinforcing, table 2.1N | $\gamma_s$ | 1.15 |
| Design yield strength of reinforcement | $f_{yd}$ (N/mm²) | 435 |
| Modulus of elasticity of reinforcement | $E_s$ (N/mm²) | 200000 |
| for $f_{ck}$ < 50MPa (3.19) | l | 0.8 |
| for $f_{ck}$ < 50MPa (3.21) | h | 1.00 |
| | $k_1$ | 0.44 |
| | $k_2$ | 1.25 |
| (for $f_{ck}$ < 50MPa )Ultimate concrete strain (table 3.1) | $e_{cu2}$ | 0.0035 |
| Ratio of the redistributed moment to the elastic bending moment | d | 1.00 |
| | $(x/d)_{lim}$ | 0.45 |
| Strain in concrete, max value (table 3.1) | $\varepsilon_c$ (max) | 0.0035 |
| Strain in concrete, min value (table 3.1) | $\varepsilon_c$ (min) | 0.00175 |
| Normalized moment | m | 0.0077 |
| Normalized section capacity as a singly reinforced beam | $m_{lim}$ | 0.2942 |
| | $x_{lim}$(mm) | 109.3120 |
| **Reinforcement** | | |
| | If m<$m_{lim}$: | **APPLIED** |
| Normalized steel ratio | w | 0.00774 |
| Longitudinal reinforcement area in tensile | $A_s$ (cm²) | 0.615 |
| | If m>$m_{lim}$: | **NOT APPLIED** |
| | $w_{lim}$ | 0.3584 |
| Depth to the compression steel, measured from the concrete compression face | d´ (mm) | 56 |
| | w´ | -0.371798975 |
| | w | -0.013398975 |
| Stress in the compression steel | $f_s$´ (N/mm²) | 341.3934426 |
| Longitudinal reinforcement area in compression | $A_s$´(cm²) (up for $M_d$+) | Not required |
| Longitudinal reinforcement area in tensile | $A_s$ (cm²) (bottom for $M_d$+) | -1.07 |

| | | |
|---|---|---|
| OVERALL Required Md | $A_s'$ ($cm^2$) (up for $M_d$ +) | 0.000 |
| OVERALL Required Md | $A_s$ ($cm^2$)(bottom for $M_d$ +) | 0.615 |
| The tensile is in both faces | T (kN) | 39 |
| Shear effort (6.2.3 (7), EN-1992-1-1) | $V_E$ (kN) | 0 |
| Reinf. in each face | $A_s$ ($cm^2$) | 0.449 |
| Total necessary reinf. In top face | $A_s$ ($cm^2$)(TOTAL) | **0.45** |
| Total necessary reinf. In low face (tensile face) | $A_s$ ($cm^2$)(TOTAL) | **1.06** |

**Disposed reinforcement:**

| | | |
|---|---|---|
| Diameter of bar | ϕ (mm) | 12 |
| Bar spacing | s (m) | 200 |
| Nº of reinf.layers | n | 1 |
| Area provided | A ($cm^2$) | 5.655 |
| | additional reinforcement | |
| Diameter of bar | ϕ (mm) | 0 |
| Bar spacing | s (m) | 200 |
| Area provided | A ($cm^2$) | 0.000 |
| | $A_{total}$ ($cm^2$) | 5.655 |
| | **OK Flexure** | **19%** |
| - | - | - |
| - | - | - |

**Minimum reinforcement EN-1992-1-1**

| | | |
|---|---|---|
| | Section type | WALL (horizontal) |
| | minimum ratio | **0.001600** |
| Minimum reinforcement for each face | $As_{min}$ ($cm^2$) | 3.904 |
| - | - | - |
| Reinforcement provided | $A_{total}$ ($cm^2$) | **5.65** |
| | **OK Minimum reinforcement** | **69%** |

**Maximum reinforcement EN-1992-1-1**

| | | |
|---|---|---|
| | maximum ratio | **0.040** |
| | $As_{max}$ ($cm^2$) | 120 |
| | **OK maximum reinforcement** | **5%** |
| | $s_{max}$ (mm) | 400 |
| | | **OK** |

| SHEAR REINFORCEMENT CALCULATION | | | |
|---|---|---|---|
| | | | EN 1992-1 AND EN 1992-2 |
| **Geometry and materials** | | | |
| Overall depth of the cross section | $h$ | [m] | 0.30 |
| Distance from the tension fiber to the centroid of the tensile reinforcement | $d'$ | [m] | 0.05 |
| Effective depth | $d$ | [m] | 0.25 |
| Smallest width of the cross section in the tensile area | $b_w$ | [m] | 1.00 |
| Number of grouted metal ducts in the web | $N_{ducts}$ | | 0 |
| Diamenter of the duct | $\phi_{duct}$ | [mm] | 0 |
| Nominal web thickness considering the PT ducts | $b_{w,nom}$ | [m] | 1.00 |
| Characteristic compressive cylinder strength of concrete at 28 days | $f_{ck}$ | [MPa] | 25 |
| Partial factor for concrete | $\gamma_c$ | | 1.2 |
| Characteristic yield strength of shear reinforcement | $f_{ywk}$ | [MPa] | 500 |
| Partial factor for reinforcing steel | $\gamma_s$ | | 1 |
| Area of tensile reinforcement | $A_{sl}$ | [$cm^2$] | 5.65 |
| Area of concrete cross section | $A_c$ | [$m^2$] | 0.30 |
| **Forces** | | | |
| Axial force in the cross section due to loading or the acing effect of prestressing ($N_{Ed}$ > 0 for compression) | $N_{Ed}$ | [kN] | -39.0 |
| Design value of the applied shear force | $V_{Ed}$ | [kN] | 14.0 |
| **Members not requiring shear reinforcement** | | | |
| | $k$ | | 1.9 |
| | $\rho_l$ | | 0.0023 |
| | $\sigma_{cp}$ | [MPa] | -0.13 |
| | $C_{Rd,c}$ | | 0.15 |
| | $v_{min}$ | [MPa] | 0.46 |
| | $k_1$ | | 0.15 |
| Design value for the shear resistance | **$V_{Rd,c}$** | **[kN]** | **121.7** |

## Losa superior

| ARMADO LOSA SUPERIOR | | |
|---|---|---|
| Armadura longitudinal/transversal (cara externa) | Armadura longitudinal/transversal (cara interna) | Armadura de cortante |
| Ø12@200mm (5,65cm²/m) | Ø12@200mm (5,65cm²/m) | No requiere armado a cortante |

| FLEXURE REINFORCEMENT CALCULATION | | |
|---|---|---|
| REF: EN-1992-1-1 | | |
| **Section inputs & material** | | |
| Flexure design moment | $M_d$ (KNm) | 6 |
| Section width | b (mm) | 1000 |
| Section heigth | h(mm) | 300 |
| Minimum cover | r (mm) | 50 |
| Effective section heigth | d (mm) | 244 |
| Specified compressive strength of concrete | $f_{ck}$(N/mm²) | 25 |
| Coeff. for long term effects in compressive strength (chapter 3.1.6 EN-1992-1-1) | $a_{cc}$ | 0.85 |
| Partial factor for concrete, table 2.1N | $\gamma_c$ | 1.5 |
| Design value of concrete compressive strength $f_{cd} = \alpha_{cc} f_{ck} / \gamma_C$ | $f_{cd}$ (N/mm²) | 14.17 |
| Mean tensile strength (according to table 3.1 EN 1992-1-1) | $f_{ctm}$ (N/mm²) | 2.6 |
| Specified yield strength of reinforcement | $f_{yk}$ (N/mm²) | 500 |
| Partial factor for reinforcing, table 2.1N | $\gamma_s$ | 1.15 |
| Design yield strength of reinforcement | $f_{yd}$ (N/mm²) | 435 |
| Modulus of elasticity of reinforcement | $E_s$ (N/mm²) | 200000 |
| for $f_{ck}$ < 50MPa (3.19) | l | 0.8 |
| for $f_{ck}$ < 50MPa (3.21) | h | 1.00 |
| | $k_1$ | 0.44 |
| | $k_2$ | 1.25 |
| (for $f_{ck}$ < 50MPa )Ultimate concrete strain (table 3.1) | $e_{cu2}$ | 0.0035 |
| Ratio of the redistributed moment to the elastic bending moment | d | 1.00 |
| | $(x/d)_{lim}$ | 0.45 |
| Strain in concrete, max value (table 3.1) | $\varepsilon_c$ (max) | 0.0035 |
| Strain in concrete, min value (table 3.1) | $\varepsilon_c$ (min) | 0.00175 |
| Normalized moment | m | 0.0071 |
| Normalized section capacity as a singly reinforced beam | $m_{lim}$ | 0.2942 |
| | $x_{lim}$(mm) | 109.3120 |
| **Reinforcement** | | |
| | If m<$m_{lim}$: | **APPLIED** |
| Normalized steel ratio | w | 0.00714 |
| Longitudinal reinforcement area in tensile | $A_s$ (cm²) | 0.568 |
| | If m>$m_{lim}$: | **NOT APPLIED** |
| | $w_{lim}$ | 0.3584 |
| Depth to the compression steel, measured from the concrete compression face | d´ (mm) | 56 |
| | w´ | -0.37256838 |
| | w | -0.01416838 |
| Stress in the compression steel | $f_s$´ (N/mm²) | 341.3934426 |
| Longitudinal reinforcement area in compression | $A_s$´(cm²) (up for $M_d$+) | Not required |
| Longitudinal reinforcement area in tensile | $A_s$ (cm²) (bottom for $M_d$+) | -1.13 |

| | | |
|---|---|---|
| OVERALL Required Md | $A_s'$ ($cm^2$) (up for $M_d$ +) | 0.000 |
| OVERALL Required Md | $A_s$ ($cm^2$)(bottom for $M_d$ +) | 0.568 |
| The tensile is in both faces | T (kN) | 3.3 |
| Shear effort (6.2.3 (7), EN-1992-1-1) | $V_E$ (kN) | 0 |
| Reinf. in each face | $A_s$ ($cm^2$) | 0.038 |
| Total necessary reinf. In top face | $A_s$ ($cm^2$)(TOTAL) | **0.04** |
| Total necessary reinf. In low face (tensile face) | $A_s$ ($cm^2$)(TOTAL) | **0.61** |

**Disposed reinforcement:**

| | | |
|---|---|---|
| Diameter of bar | ϕ (mm) | 12 |
| Bar spacing | s (m) | 200 |
| Nº of reinf.layers | n | 1 |
| Area provided | A ($cm^2$) | 5.655 |
| | additional reinforcement | |
| Diameter of bar | ϕ (mm) | 0 |
| Bar spacing | s (m) | 200 |
| Area provided | A ($cm^2$) | 0.000 |
| | $A_{total}$ ($cm^2$) | 5.655 |
| | **OK Flexure** | **11%** |
| | - | - |
| - | - | - |

**Minimum reinforcement EN-1992-1-1**

| | | |
|---|---|---|
| | Section type | SLAB/FOUNDATION |
| | minimum ratio | **0.001352** |
| Minimum reinforcement for each face | $As_{min}$ ($cm^2$) | 3.299 |
| - | - | - |
| Reinforcement provided | $A_{total}$ ($cm^2$) | **5.65** |
| | **OK Minimum reinforcement** | **58%** |

**Maximum reinforcement EN-1992-1-1**

| | | |
|---|---|---|
| | maximum ratio | **0.040** |
| | $As_{max}$ ($cm^2$) | 120 |
| | **OK maximum reinforcement** | **5%** |
| | $s_{max}$ (mm) | 400 |
| | | **OK** |

| SHEAR REINFORCEMENT CALCULATION | | | |
|---|---|---|---|
| | | | EN 1992-1 AND EN 1992-2 |
| **Geometry and materials** | | | |
| Overall depth of the cross section | h | [m] | 0.30 |
| Distance from the tension fiber to the centroid of the tensile reinforcement | d' | [m] | 0.05 |
| Effective depth | d | [m] | 0.25 |
| Smallest width of the cross section in the tensile area | $b_w$ | [m] | 1.00 |
| Number of grouted metal ducts in the web | $N_{ducts}$ | | 0 |
| Diamenter of the duct | $\phi_{duct}$ | [mm] | 0 |
| Nominal web thickness considering the PT ducts | $b_{w,nom}$ | [m] | 1.00 |
| Characteristic compressive cylinder strength of concrete at 28 days | $f_{ck}$ | [MPa] | 25 |
| Partial factor for concrete | $\gamma_c$ | | 1.2 |
| Characteristic yield strength of shear reinforcement | $f_{ywk}$ | [MPa] | 500 |
| Partial factor for reinforcing steel | $\gamma_s$ | | 1 |
| Area of tensile reinforcement | $A_{sl}$ | [$cm^2$] | 5.65 |
| Area of concrete cross section | $A_c$ | [$m^2$] | 0.30 |
| **Forces** | | | |
| Axial force in the cross section due to loading or the acing effect of prestressing ($N_{Ed}$ > 0 for compression) | $N_{Ed}$ | [kN] | -3.7 |
| Design value of the applied shear force | $V_{Ed}$ | [kN] | 30.0 |
| **Members not requiring shear reinforcement** | | | |
| | k | | 1.9 |
| | $\rho_l$ | | 0.0023 |
| | $\sigma_{cp}$ | [MPa] | -0.01 |
| | $C_{Rd,c}$ | | 0.15 |
| | $v_{min}$ | [MPa] | 0.46 |
| | $k_1$ | | 0.15 |
| Design value for the shear resistance | **$V_{Rd,c}$** | **[kN]** | **126.1** |

### 3.8.5 Verificación Estado Límite Servicio (ELS)

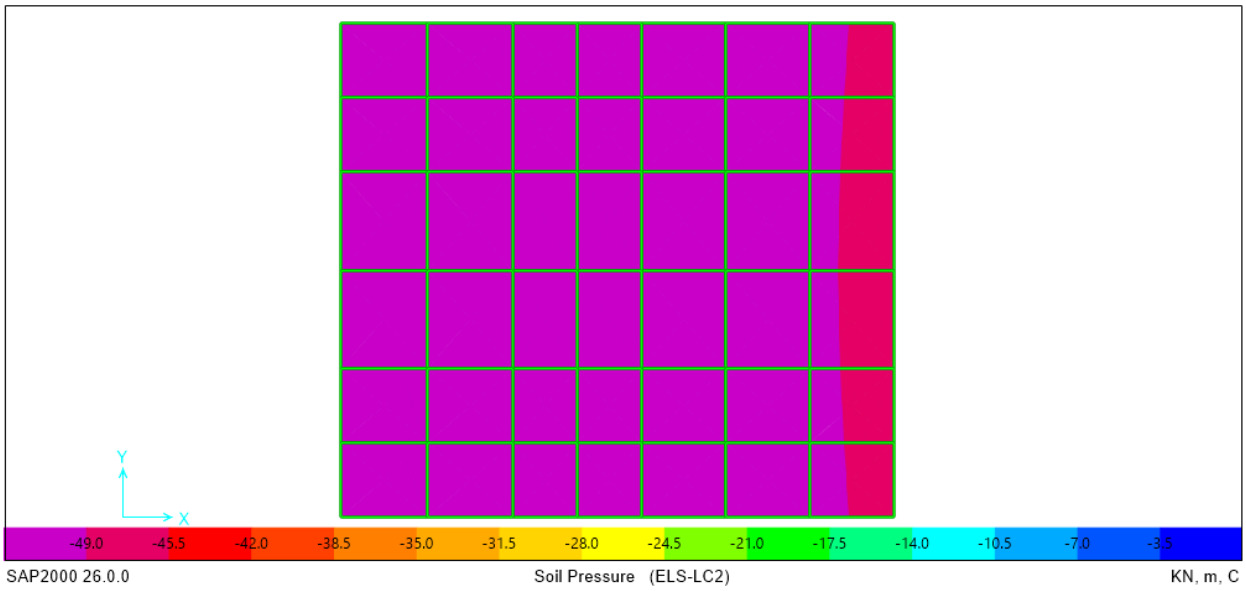
#### Comprobación abertura máxima de fisura

Se ha realizado una comprobación del máximo momento de fisuración por cada sección. A continuación, se proporciona un resumen del momento máximo resistente y del momento solicitado por tipo de sección:

| COMPROBACIÓN A FISURACIÓN | | |
|---|---|---|
| **Sección** | **$M_d$ (kNm)** | **$M_R$ (kNm)** |
| Losa base inferior | 14 | 192,60 |
| Muros | 2,55 | 48,15 |
| Losa superior | 2,9 | 48,15 |

#### Tensión máxima transmitida al terreno

La tensión máxima transmitida al terreno es de 49 kN/m².




## 3.9 Modelo de cálculo. Arqueta de desagüe

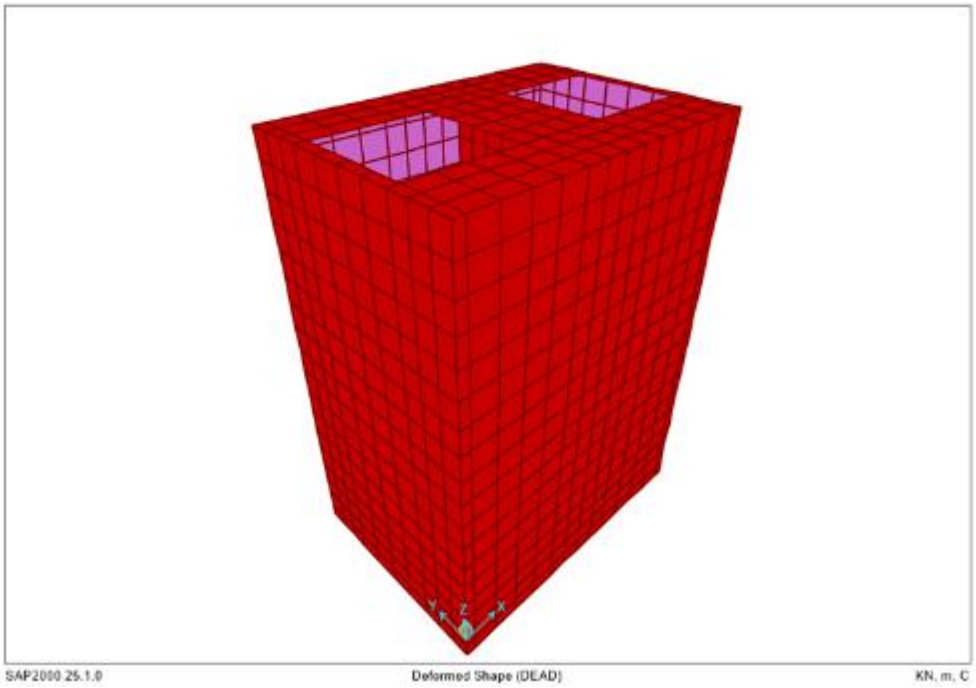
El cálculo estructural se realiza acorde al método global de análisis utilizado para cálculo de fuerzas y momentos internos de los miembros, mediante un modelo tridimensional, con el software de diseño estructural SAP2000 v25.1.0.

Este software utiliza el método de análisis elástico que puede usarse en todos los casos. El programa se basa en técnicas de cálculo matricial y elementos finitos bajo las habituales hipótesis de elasticidad lineal:

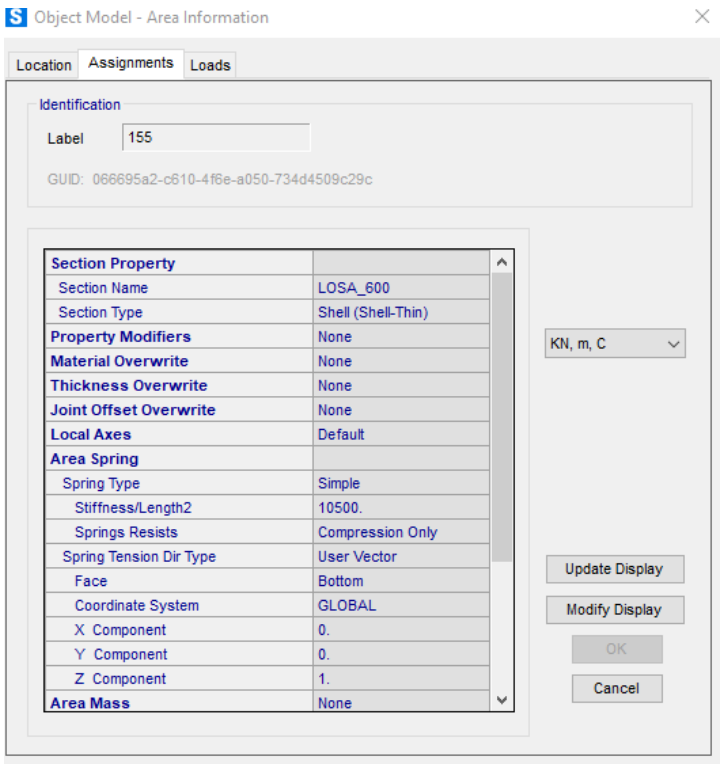
- Proporcionalidad entre tensiones y deformaciones.
- Compatibilidad de elementos estructurales.
- Balance estático local y global de cada una de las partes de la estructura

### 3.9.1 Geometría

Los muros y losas que forman la arqueta se representan mediante elementos tipo «Shell» de distintos espesores.




El módulo de balasto considerado según el terreno en la cimentación es de 10.500 kN/m$^3$.



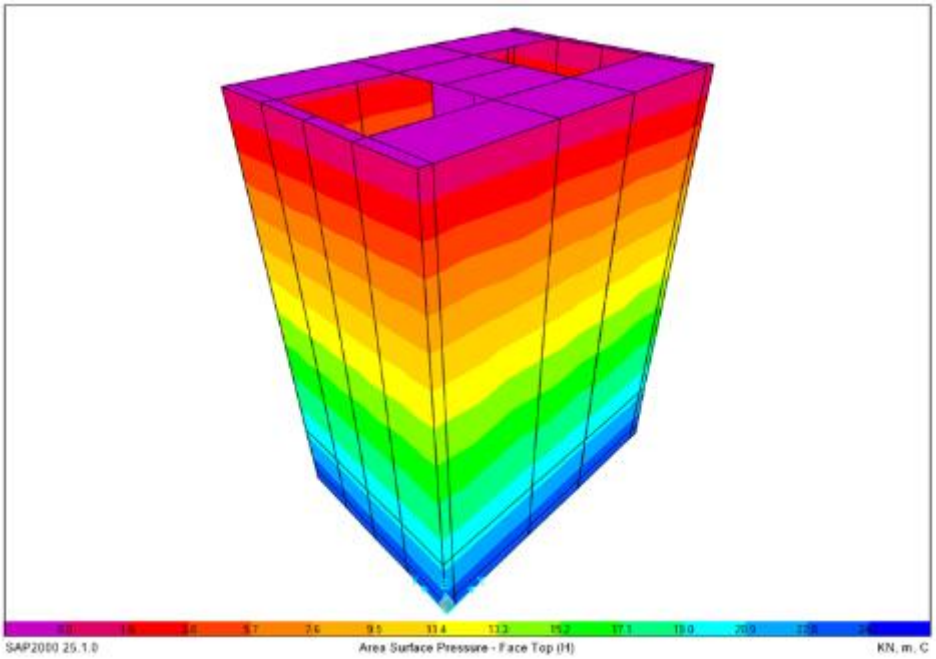

### 3.9.2 Acciones de cálculo en el modelo

**Peso propio**

El peso propio de los elementos (muros y losas de hormigón) SAP2000 lo introduce directamente con las definiciones que se han hecho de las propiedades de los elementos y los materiales. En el programa esta acción se denomina DEAD.

| Load Pattern Name | Type | Self Weight Multiplier | Auto Lateral Load Pattern |
|---|---|---|---|
| D_DEAD | Dead | 1 | |
| D_DEAD | Dead | 1 | |

**Empuje del terreno**

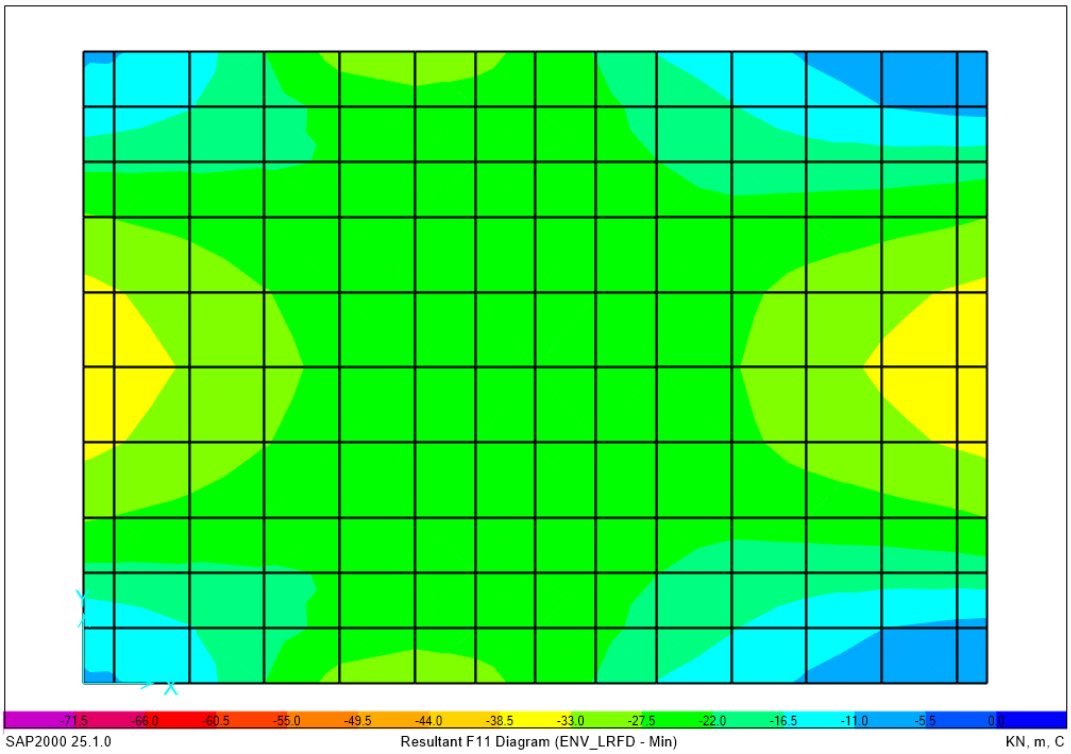


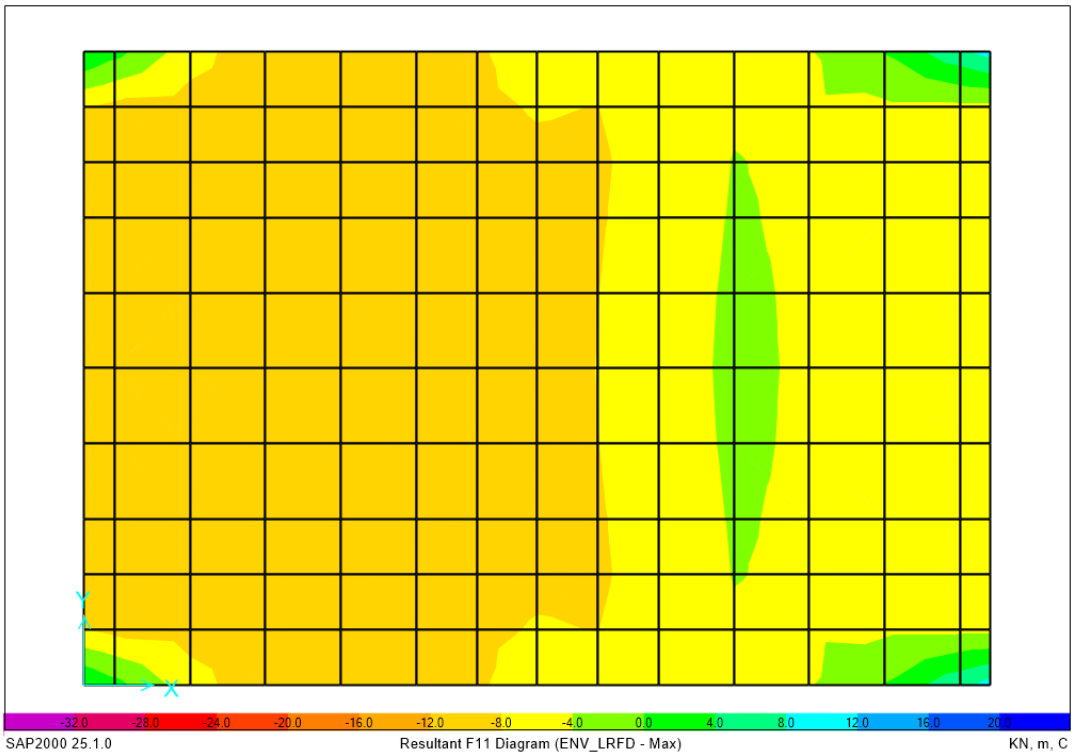

### 3.9.3 Resultados

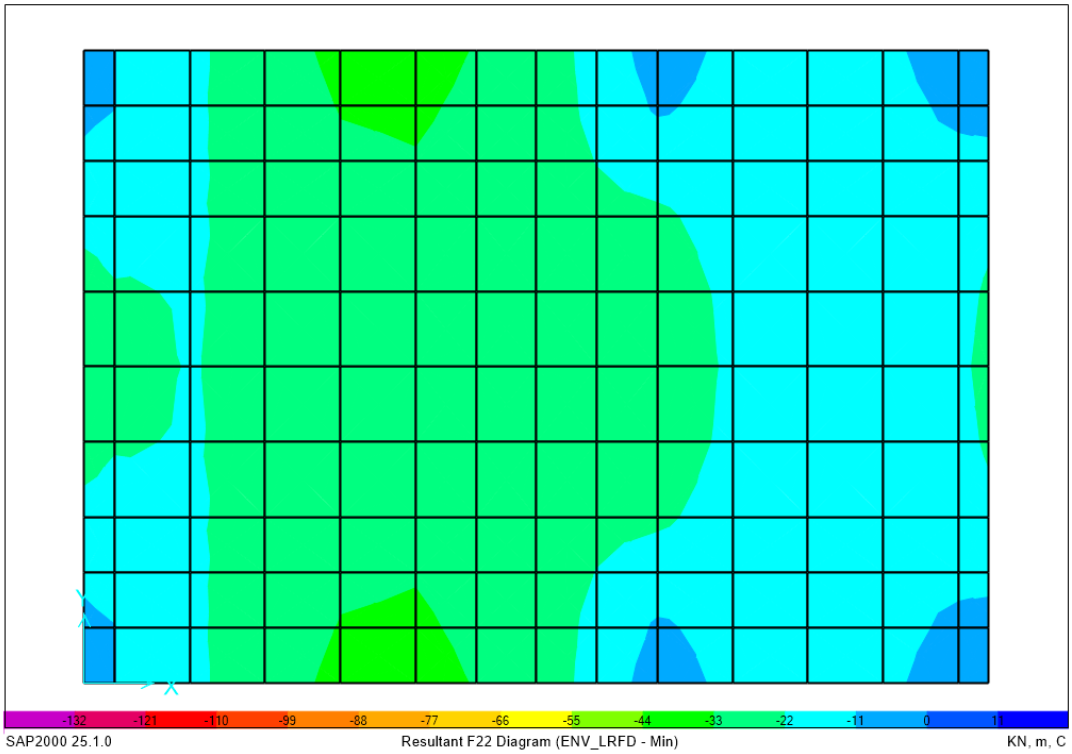
A continuación, se muestran los resultados del modelo para cada elemento estructural, diferenciando en losa inferior, muros, columnas y losa superior para todas las situaciones de diseño.

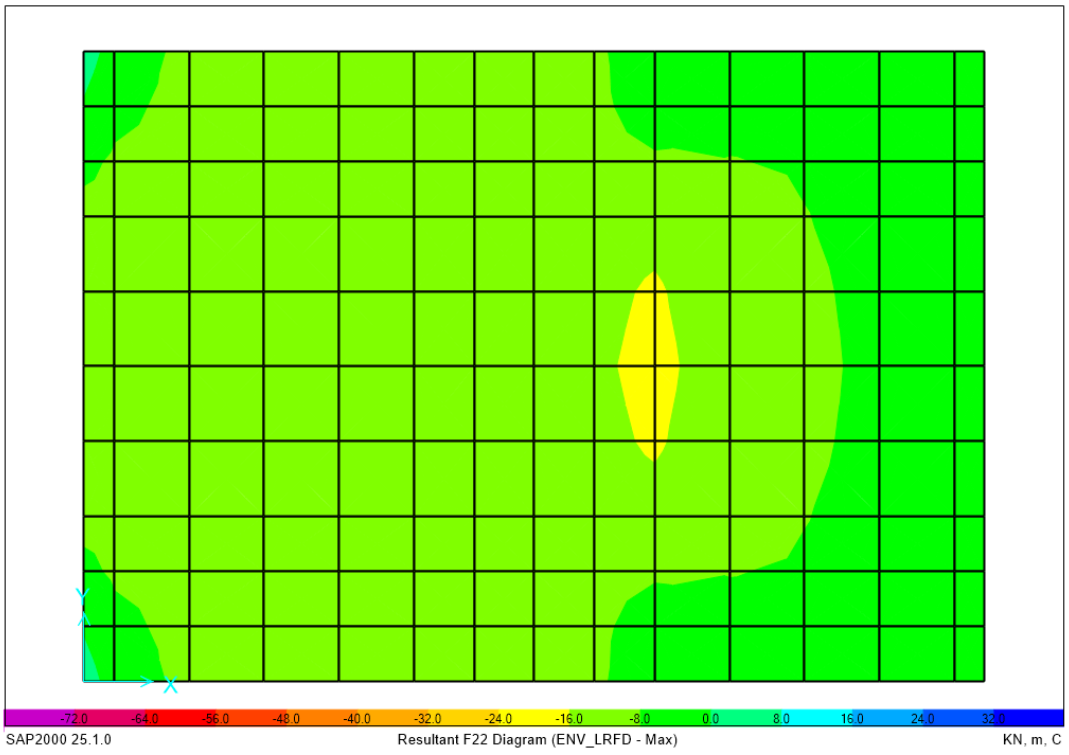
**Losa base inferior**

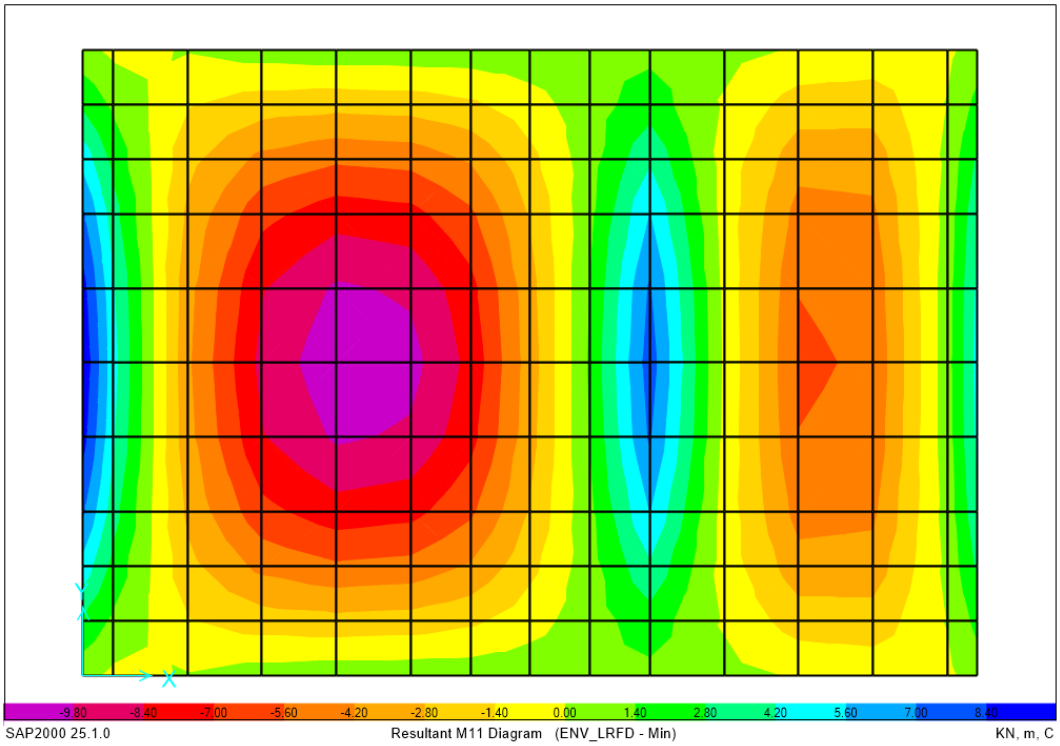
| LOSA BASE INFERIOR – ELU RESULTADOS | | | | | |
|---|---|---|---|---|---|
| | **$F_{11}$ (kN)** | **$M_{11}$ (kNm)** | **$F_{22}$ (kN)** | **$M_{22}$ (kNm)** | **$V_{max}$ (kN)** |
| **ELU (min)** | -36,78 | -10,78 | -35,71 | -9,41 | 0,88 |
| **ELU (max)** | 9,5 | 16,51 | 3,12 | 11,8 | 64,02 |

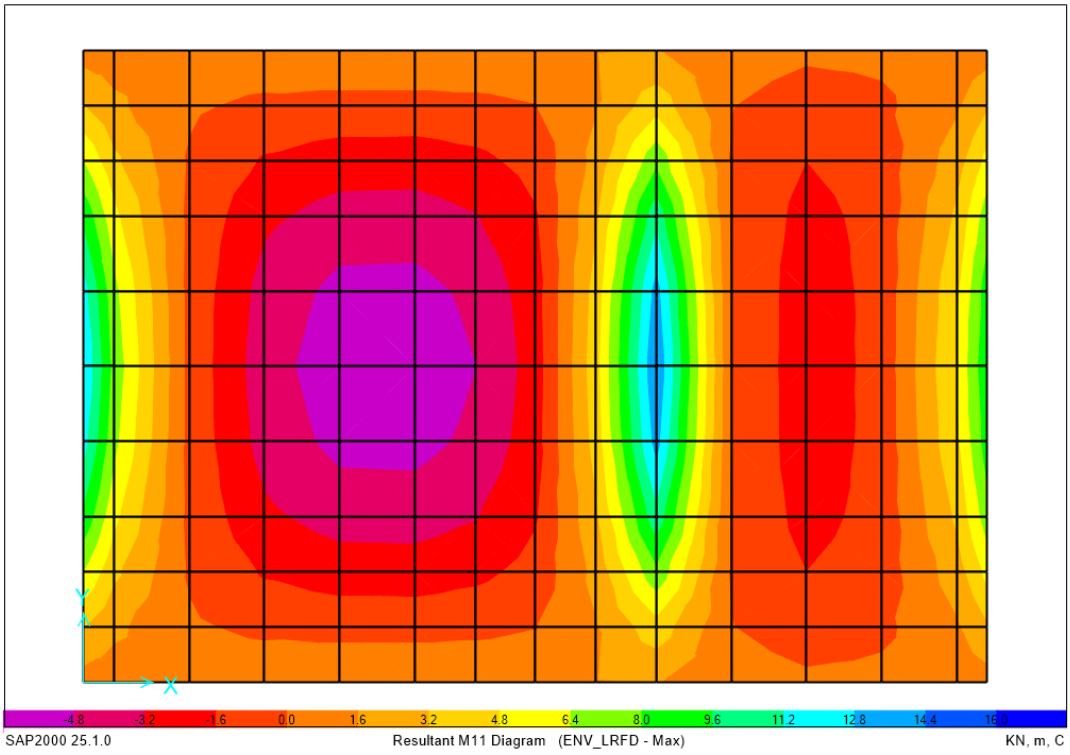

-71.5 -66.0 -60.5 -55.0 -49.5 -44.0 -38.5 -33.0 -27.5 -22.0 -16.5 -11.0 -5.5 0.0
SAP2000 25.1.0
Resultant F11 Diagram (ENV_LRFD - Min)
KN, m, C

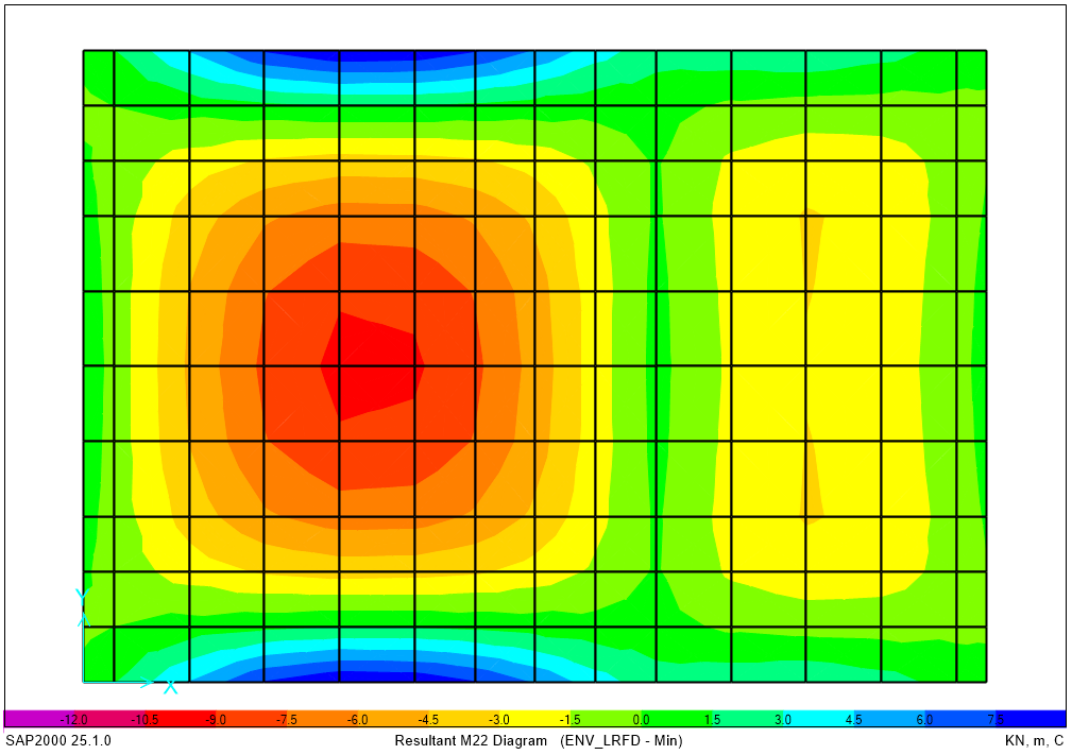

-32.0 -28.0 -24.0 -20.0 -16.0 -12.0 -8.0 -4.0 0.0 4.0 8.0 12.0 16.0 20.0
SAP2000 25.1.0
Resultant F11 Diagram (ENV_LRFD - Max)
KN, m, C

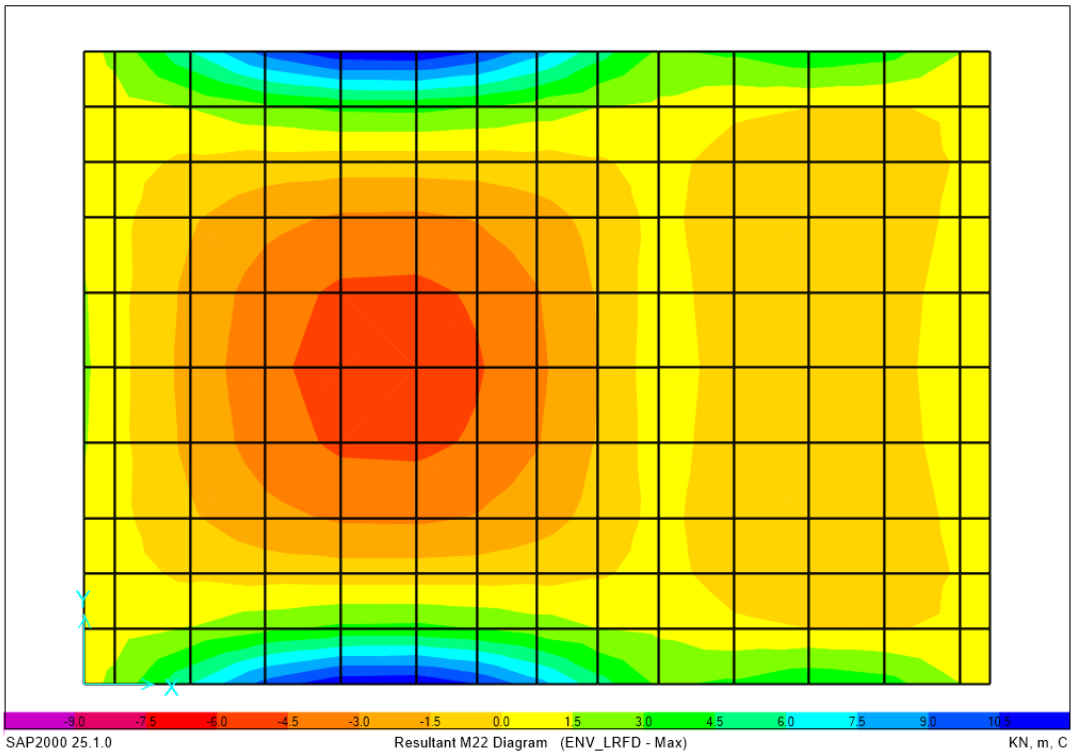

-132 -121 -110 -99 -88 -77 -66 -55 -44 -33 -22 -11 0 11
SAP2000 25.1.0
Resultant F22 Diagram (ENV_LRFD - Min)
KN, m, C

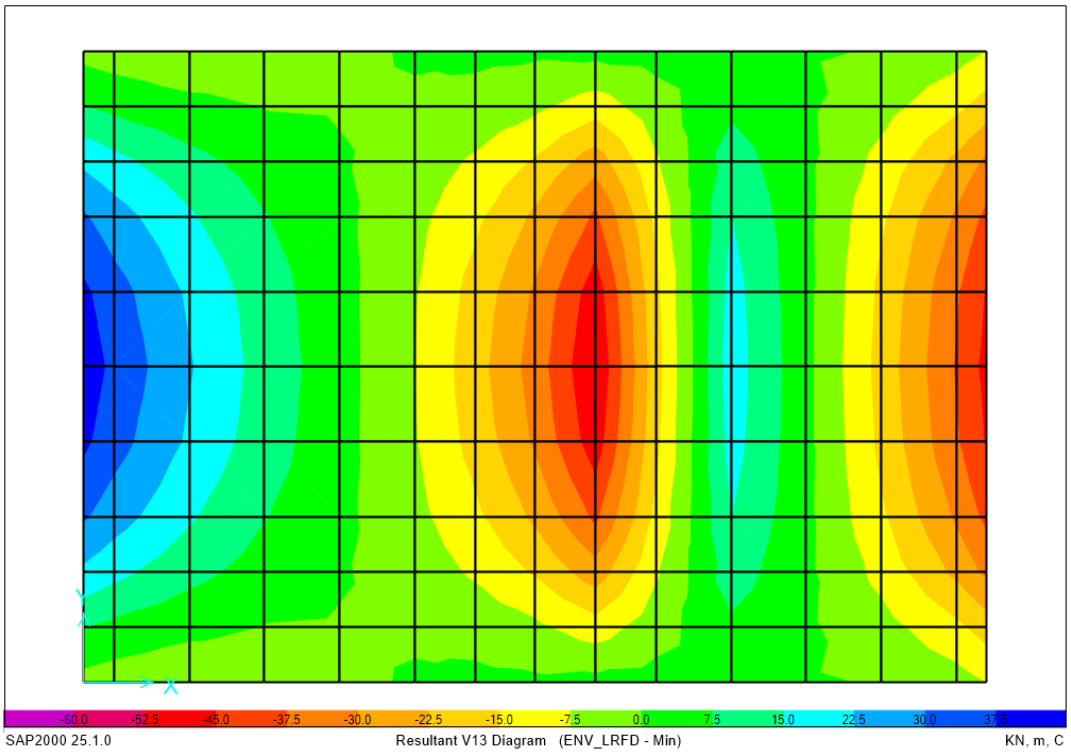

-72.0 -64.0 -56.0 -48.0 -40.0 -32.0 -24.0 -16.0 -8.0 0.0 8.0 16.0 24.0 32.0
SAP2000 25.1.0
Resultant F22 Diagram (ENV_LRFD - Max)
KN, m, C

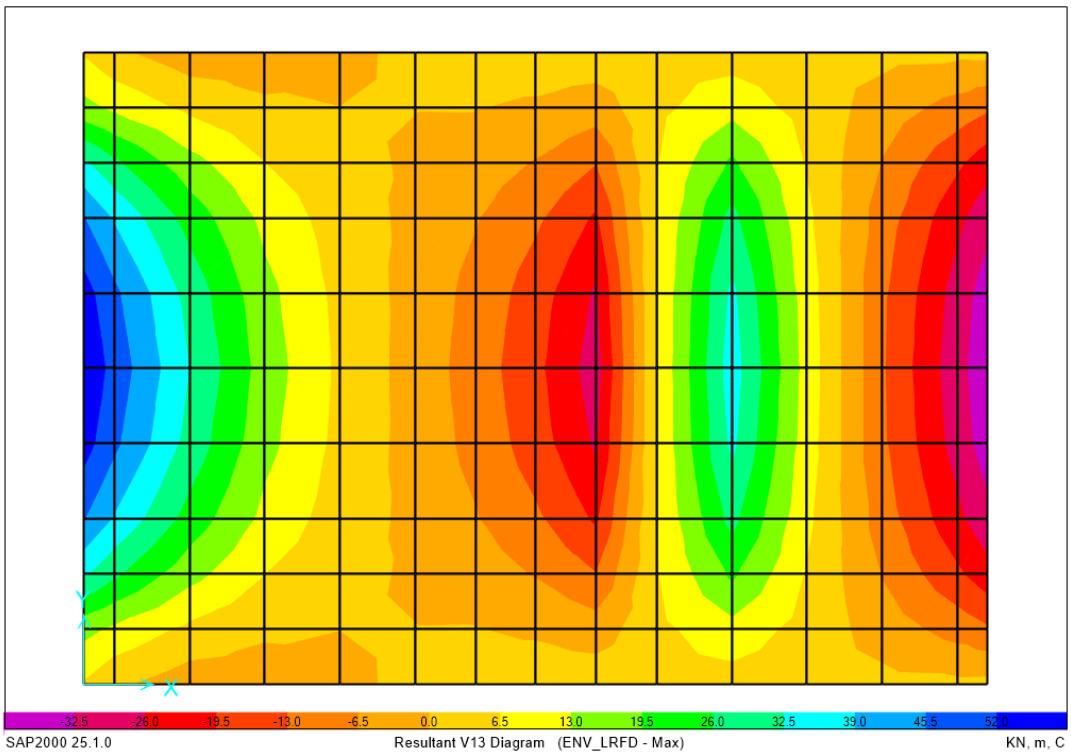

-9.80 -8.40 -7.00 -5.60 -4.20 -2.80 -1.40 0.00 1.40 2.80 4.20 5.60 7.00 8.40
SAP2000 25.1.0
Resultant M11 Diagram (ENV_LRFD - Min)
KN, m, C

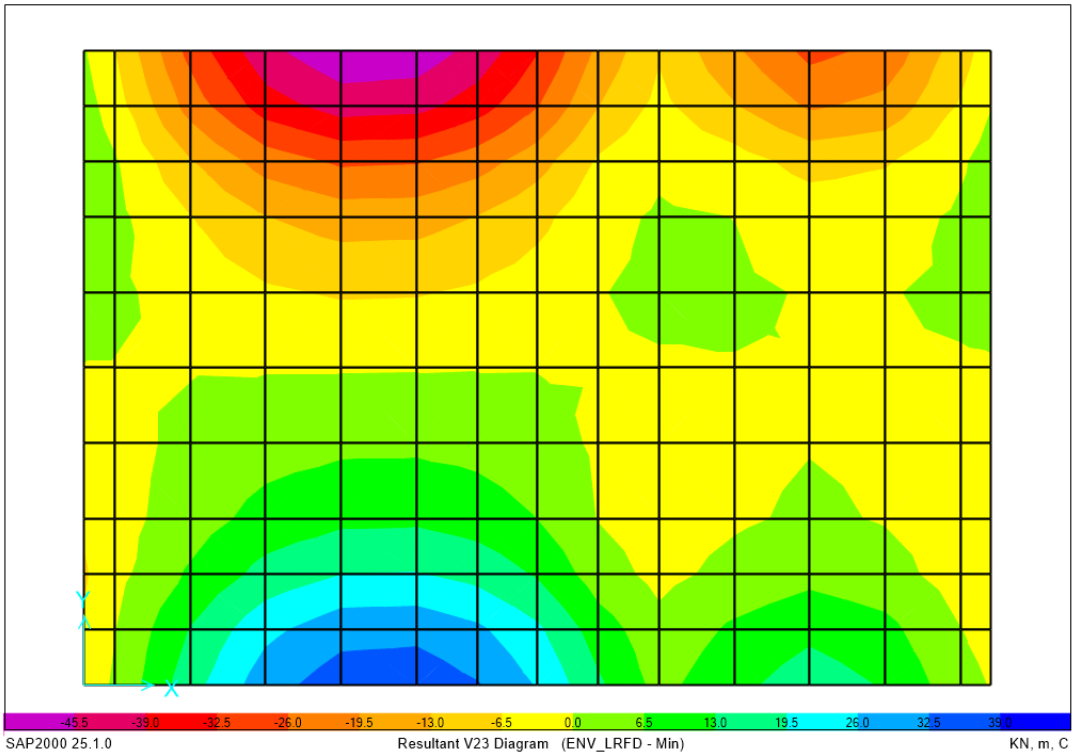

-4.8 -3.2 -1.6 0.0 1.6 3.2 4.8 6.4 8.0 9.6 11.2 12.8 14.4 16.0
SAP2000 25.1.0
Resultant M11 Diagram (ENV_LRFD - Max)
KN, m, C

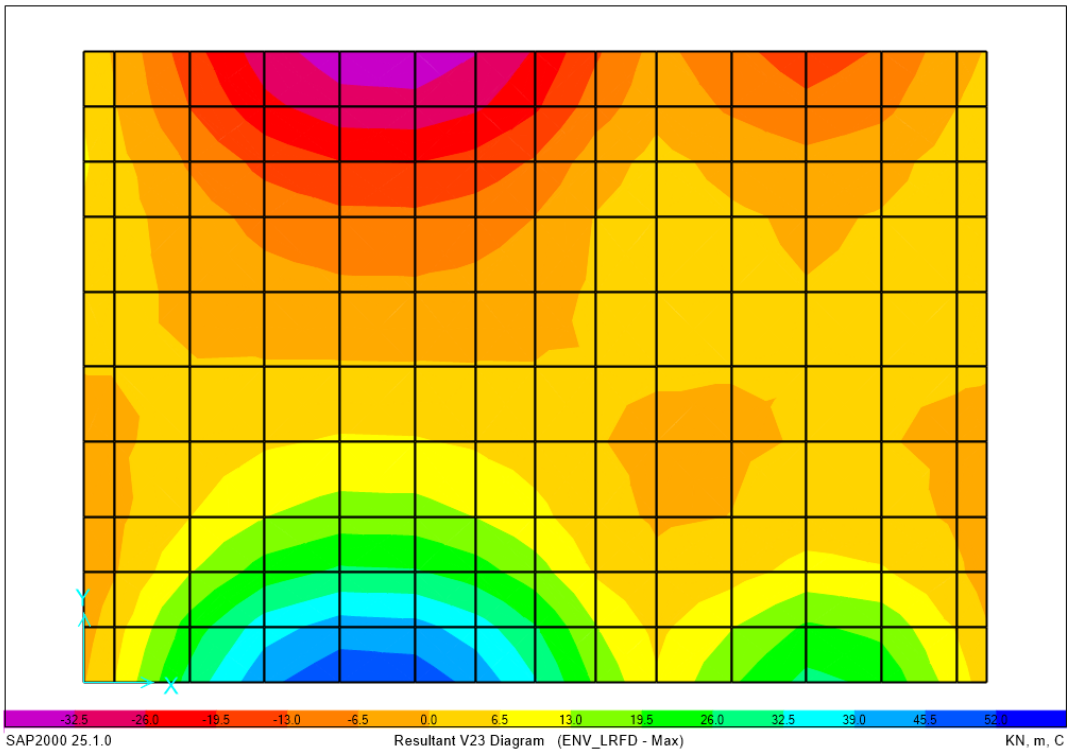

-12.0 -10.5 -9.0 -7.5 -6.0 -4.5 -3.0 -1.5 0.0 1.5 3.0 4.5 6.0 7.5
SAP2000 25.1.0
Resultant M22 Diagram (ENV_LRFD - Min)
KN, m, C


-9.0 -7.5 -6.0 -4.5 -3.0 -1.5 0.0 1.5 3.0 4.5 6.0 7.5 9.0 10.5
SAP2000 25.1.0
Resultant M22 Diagram (ENV_LRFD - Max)
KN, m, C


-60.0 -52.5 -45.0 -37.5 -30.0 -22.5 -15.0 -7.5 0.0 7.5 15.0 22.5 30.0 37.5
SAP2000 25.1.0
Resultant V13 Diagram (ENV_LRFD - Min)
KN, m, C

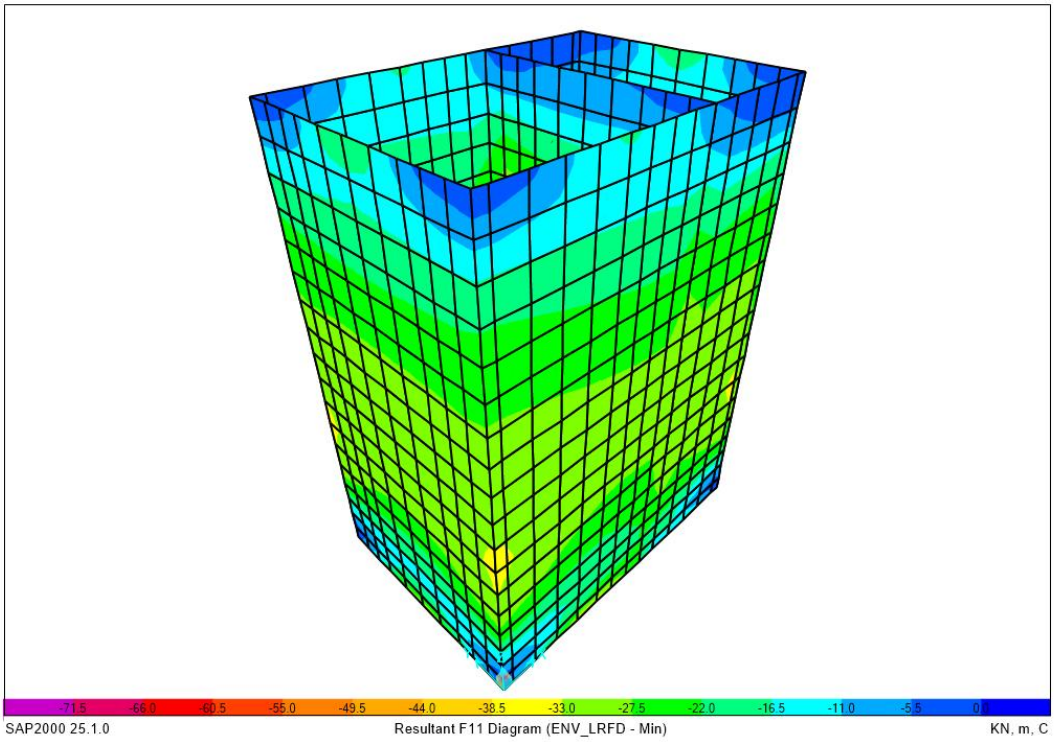

-32.5 -26.0 -19.5 -13.0 -6.5 0.0 6.5 13.0 19.5 26.0 32.5 39.0 45.5 52.0
SAP2000 25.1.0
Resultant V13 Diagram (ENV_LRFD - Max)
KN, m, C

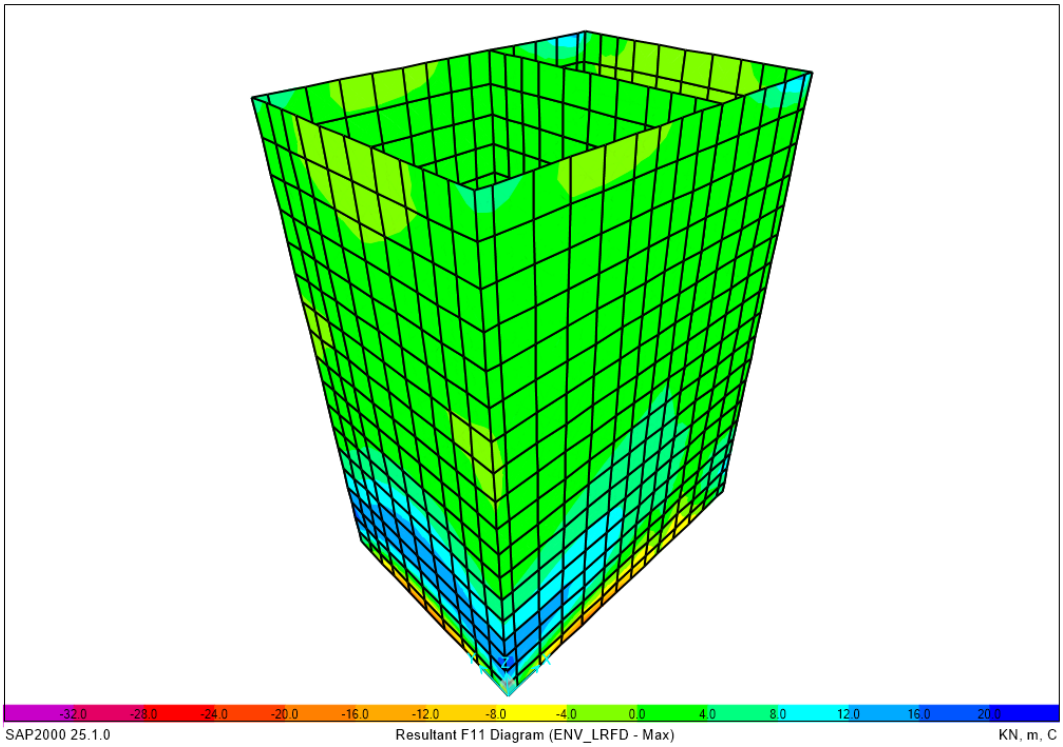

-45.5 -39.0 -32.5 -26.0 -19.5 -13.0 -6.5 0.0 6.5 13.0 19.5 26.0 32.5 39.0
SAP2000 25.1.0
Resultant V23 Diagram (ENV_LRFD - Min)
KN, m, C

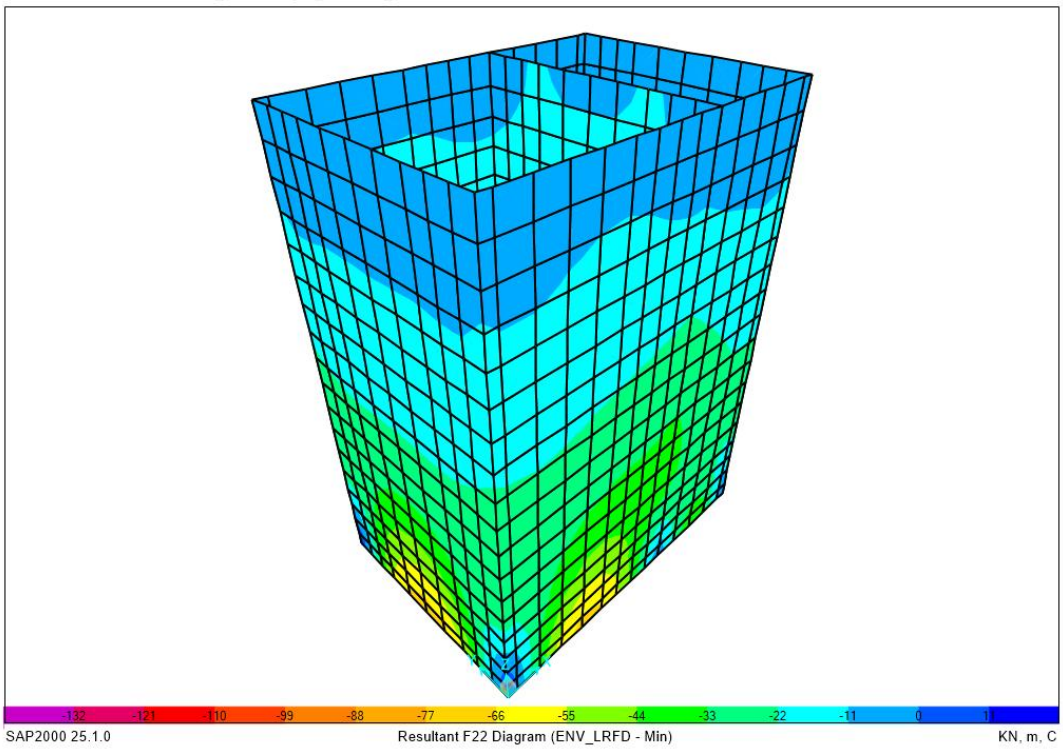

-32.5 -26.0 -19.5 -13.0 -6.5 0.0 6.5 13.0 19.5 26.0 32.5 39.0 45.5 52.0
SAP2000 25.1.0
Resultant V23 Diagram (ENV_LRFD - Max)
KN, m, C

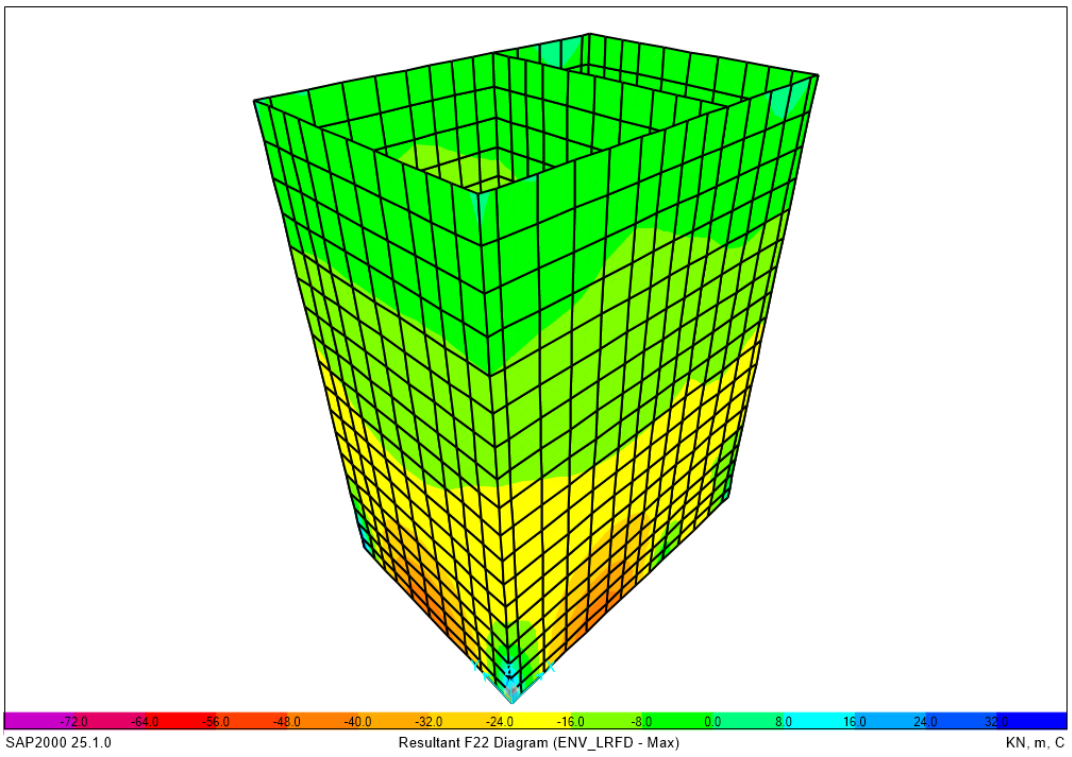
**Muros**

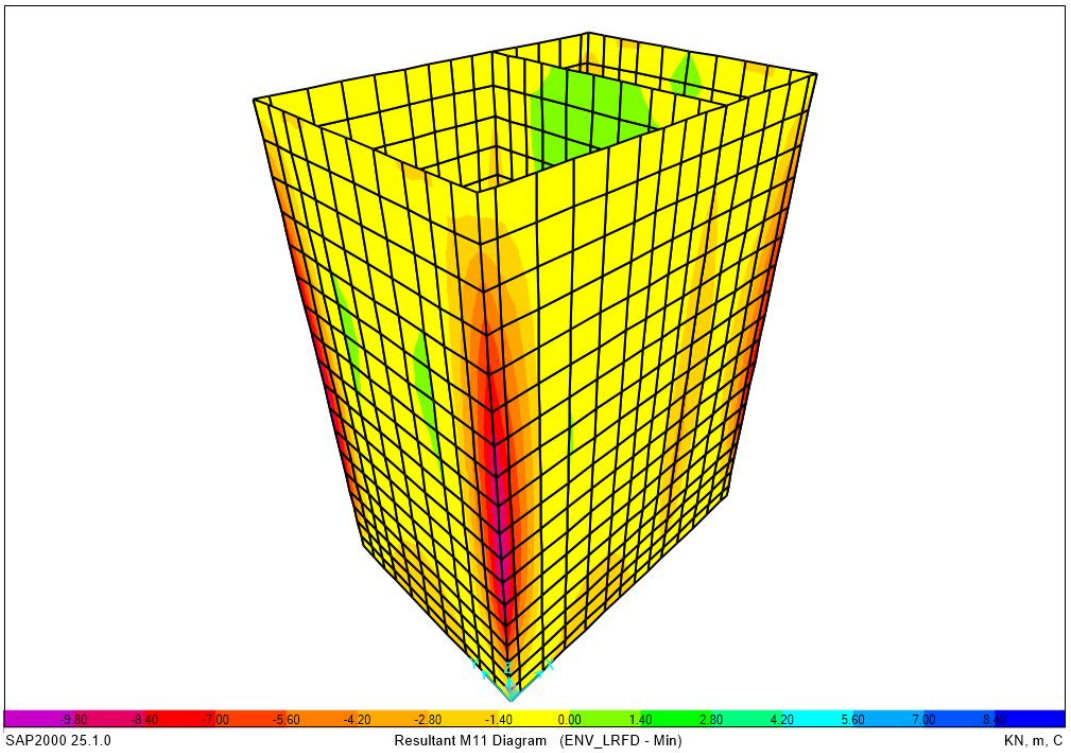
| MUROS – LRFD RESULTADOS | | | | | |
|---|---|---|---|---|---|
| | **$F_{11}$ (kN)** | **$M_{11}$ (kNm)** | **$F_{22}$ (kN)** | **$M_{22}$ (kNm)** | **Vmax (kN)** |
| **ELU (min)** | -48,16 | -10,6 | -140,52 | -12,7 | 0,1 |
| **ELU (max)** | 21,04 | 7 | 30,14 | 4,45 | 35,06 |

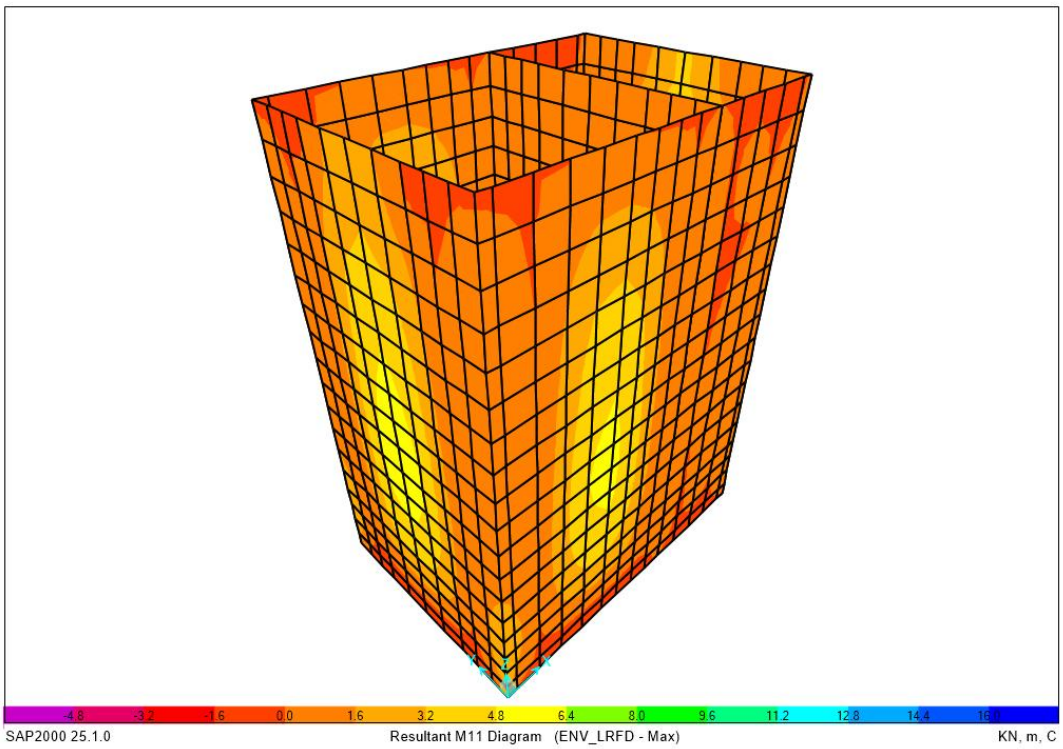


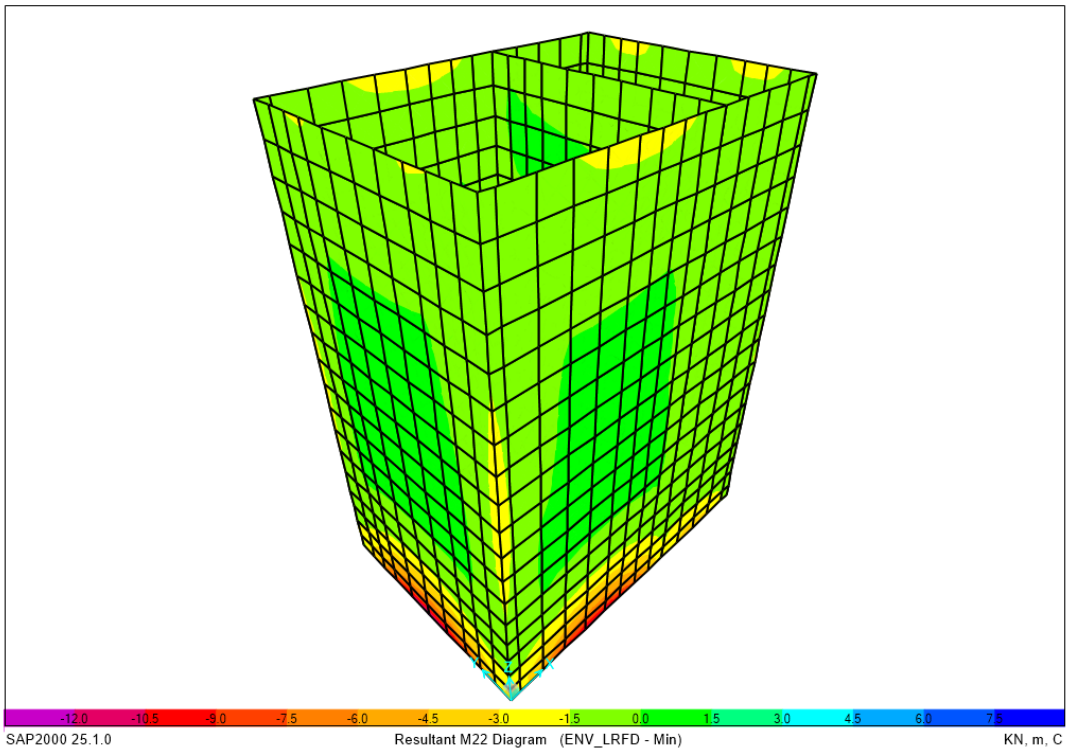



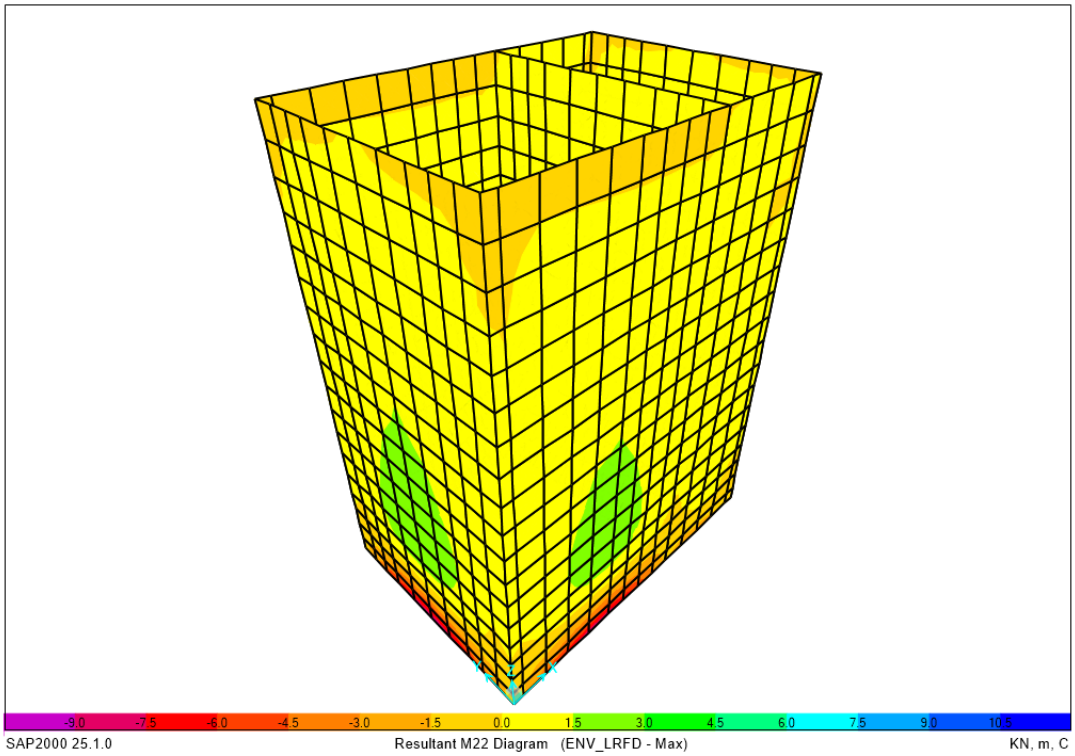

-132 -121 -110 -99 -88 -77 -66 -55 -44 -33 -22 -11 0 11
SAP2000 25.1.0
Resultant F22 Diagram (ENV_LRFD - Min)
KN, m, C

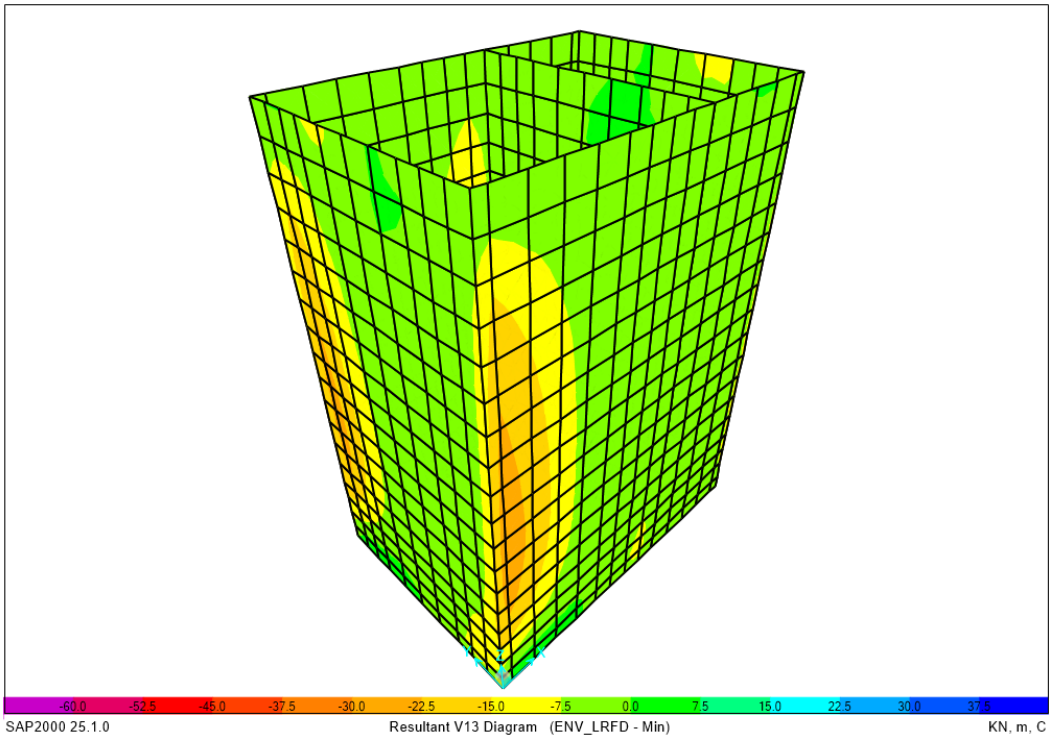

-72.0 -64.0 -56.0 -48.0 -40.0 -32.0 -24.0 -16.0 -8.0 0.0 8.0 16.0 24.0 32.0
SAP2000 25.1.0
Resultant F22 Diagram (ENV_LRFD - Max)
KN, m, C

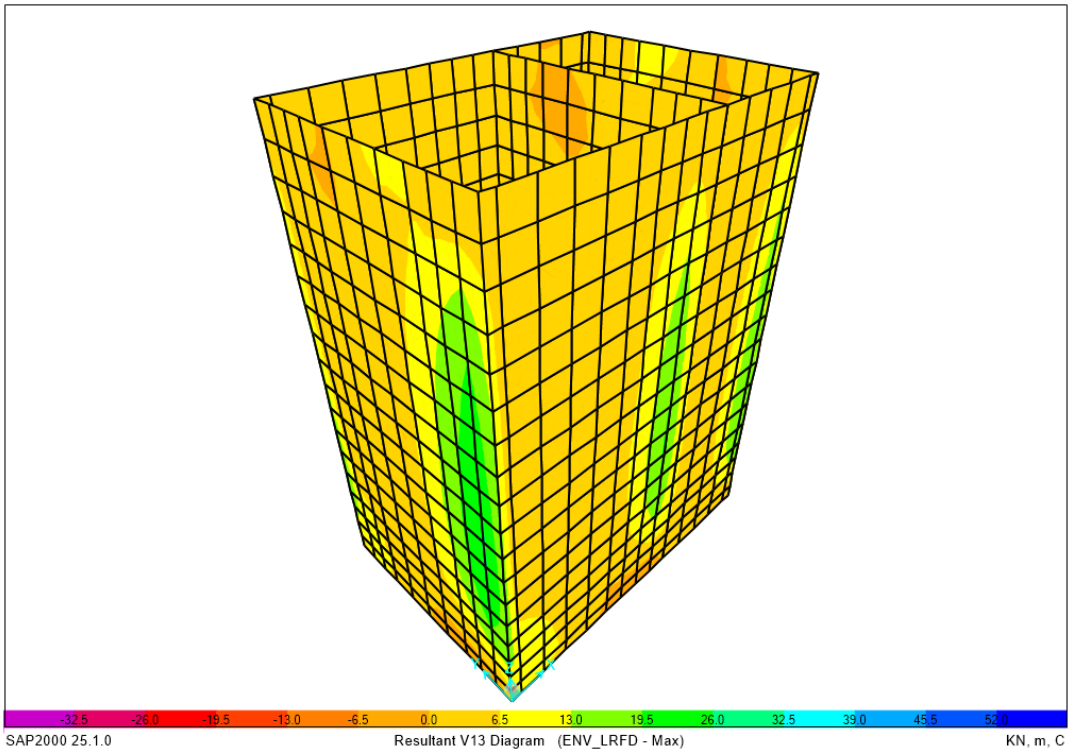

-9.80 -8.40 -7.00 -5.60 -4.20 -2.80 -1.40 0.00 1.40 2.80 4.20 5.60 7.00 8.40
SAP2000 25.1.0
Resultant M11 Diagram (ENV_LRFD - Min)
KN, m, C

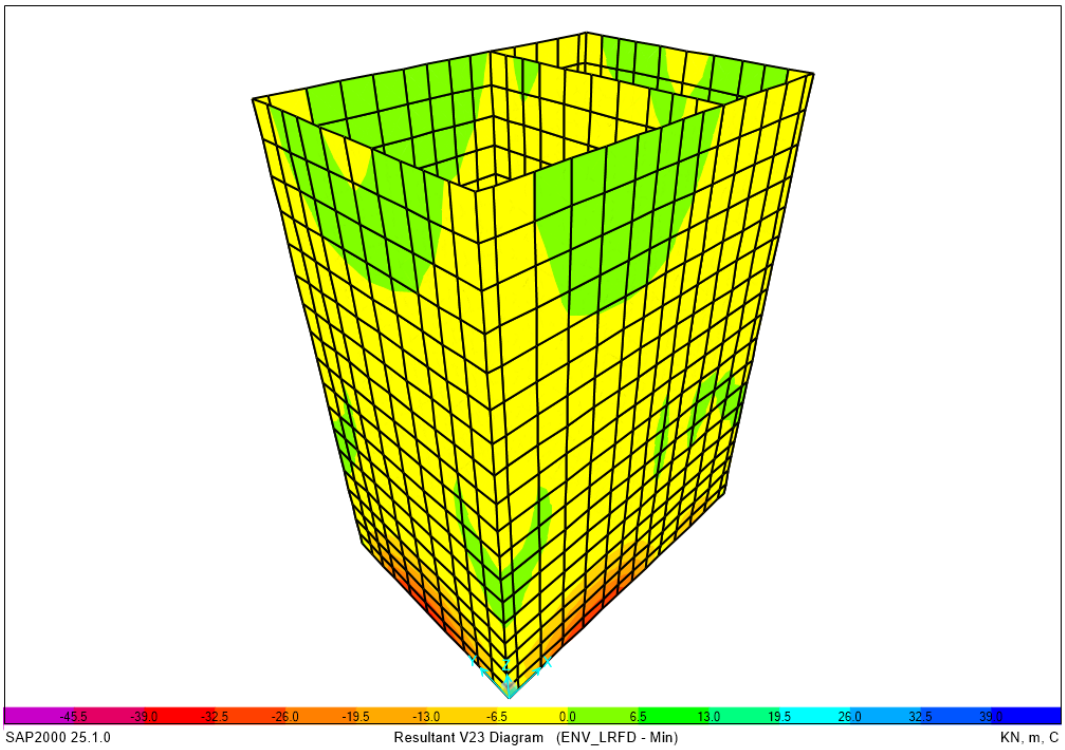

-4.8 -3.2 -1.6 0.0 1.6 3.2 4.8 6.4 8.0 9.6 11.2 12.8 14.4 16.0
SAP2000 25.1.0
Resultant M11 Diagram (ENV_LRFD - Max)
KN, m, C

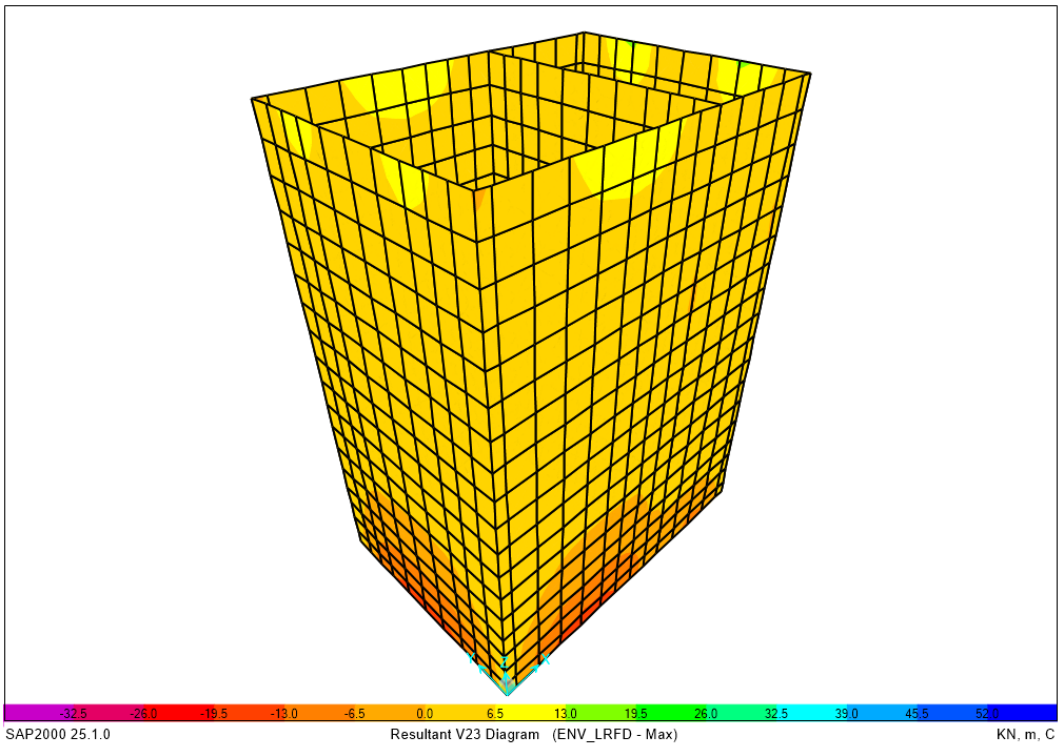

-12.0 -10.5 -9.0 -7.5 -6.0 -4.5 -3.0 -1.5 0.0 1.5 3.0 4.5 6.0 7.5
SAP2000 25.1.0
Resultant M22 Diagram (ENV_LRFD - Min)
KN, m, C


-9.0 -7.5 -6.0 -4.5 -3.0 -1.5 0.0 1.5 3.0 4.5 6.0 7.5 9.0 10.5
SAP2000 25.1.0
Resultant M22 Diagram (ENV_LRFD - Max)
KN, m, C


-60.0 -52.5 -45.0 -37.5 -30.0 -22.5 -15.0 -7.5 0.0 7.5 15.0 22.5 30.0 37.5
SAP2000 25.1.0
Resultant V13 Diagram (ENV_LRFD - Min)
KN, m, C

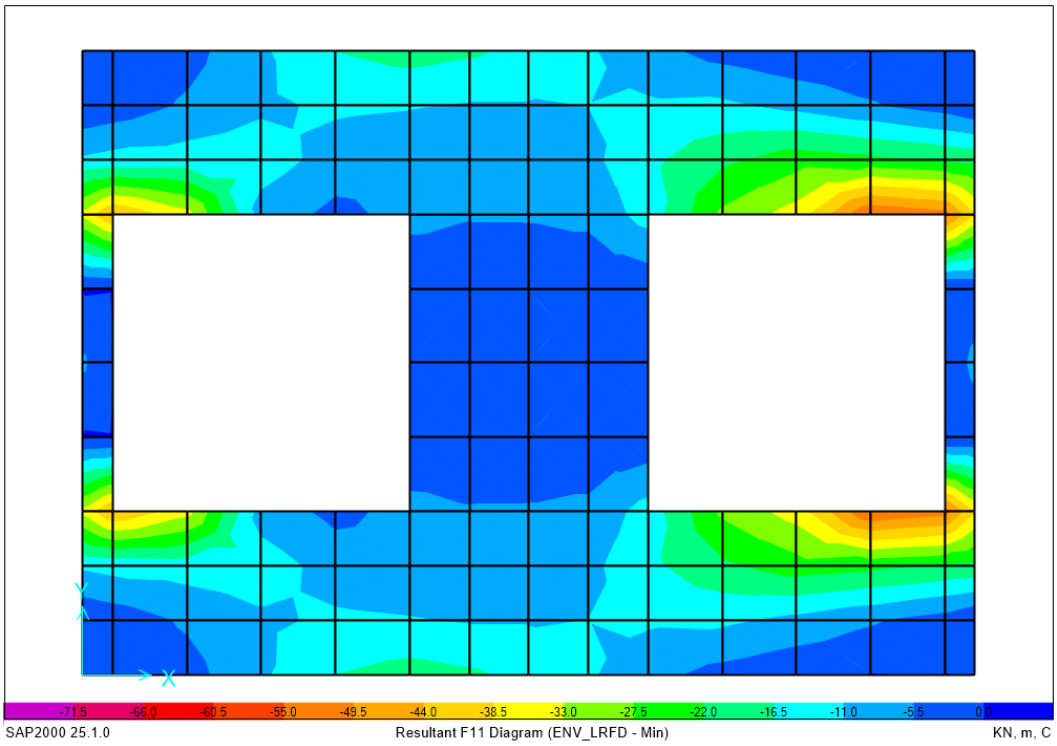

-32.5 -26.0 -19.5 -13.0 -6.5 0.0 6.5 13.0 19.5 26.0 32.5 39.0 45.5 52.0
SAP2000 25.1.0
Resultant V13 Diagram (ENV_LRFD - Max)
KN, m, C

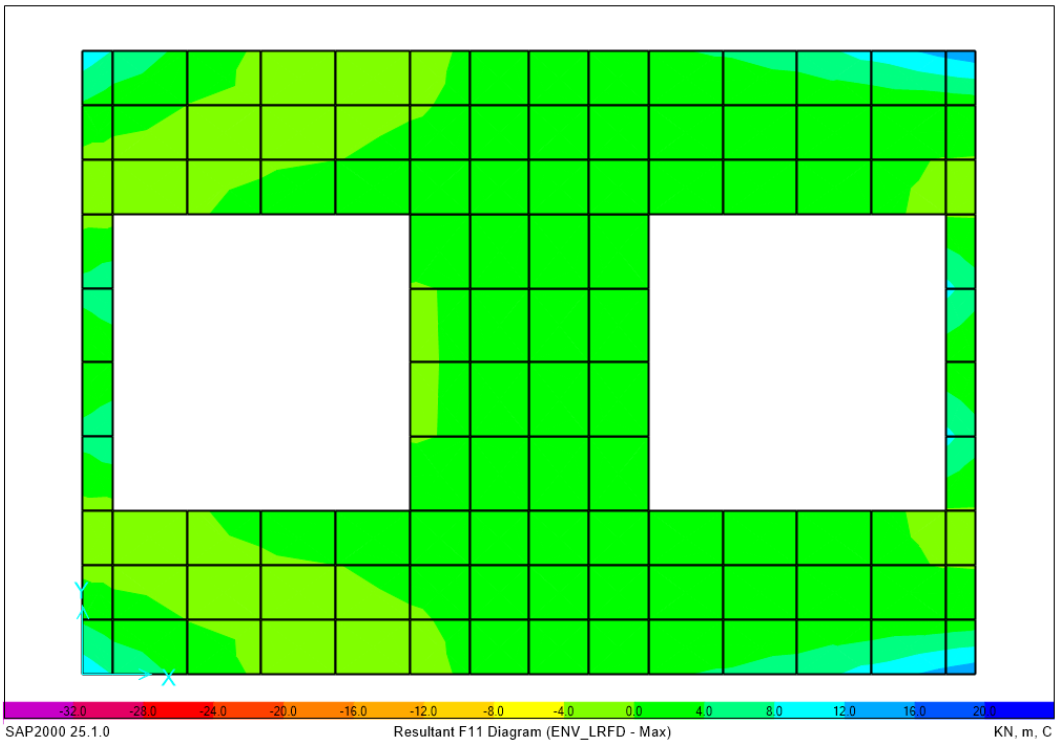

-45.5 -39.0 -32.5 -26.0 -19.5 -13.0 -6.5 0.0 6.5 13.0 19.5 26.0 32.5 39.0
SAP2000 25.1.0
Resultant V23 Diagram (ENV_LRFD - Min)
KN, m, C

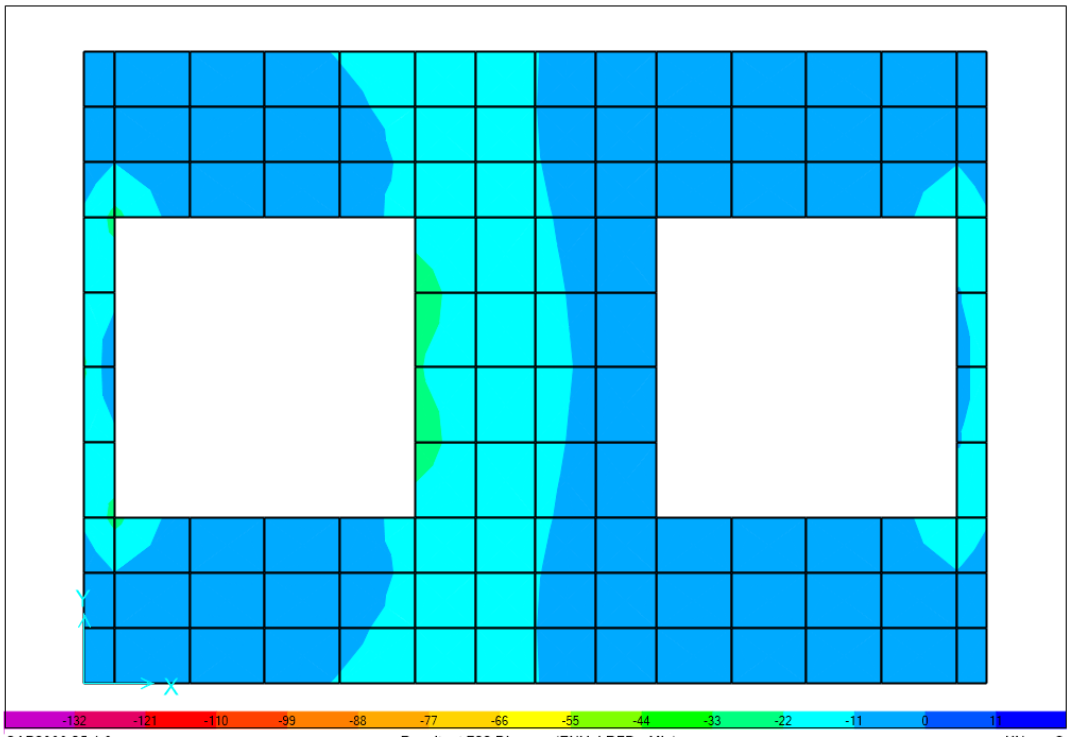

-32.5 -26.0 -19.5 -13.0 -6.5 0.0 6.5 13.0 19.5 26.0 32.5 39.0 45.5 52.0
SAP2000 25.1.0
Resultant V23 Diagram (ENV_LRFD - Max)
KN, m, C

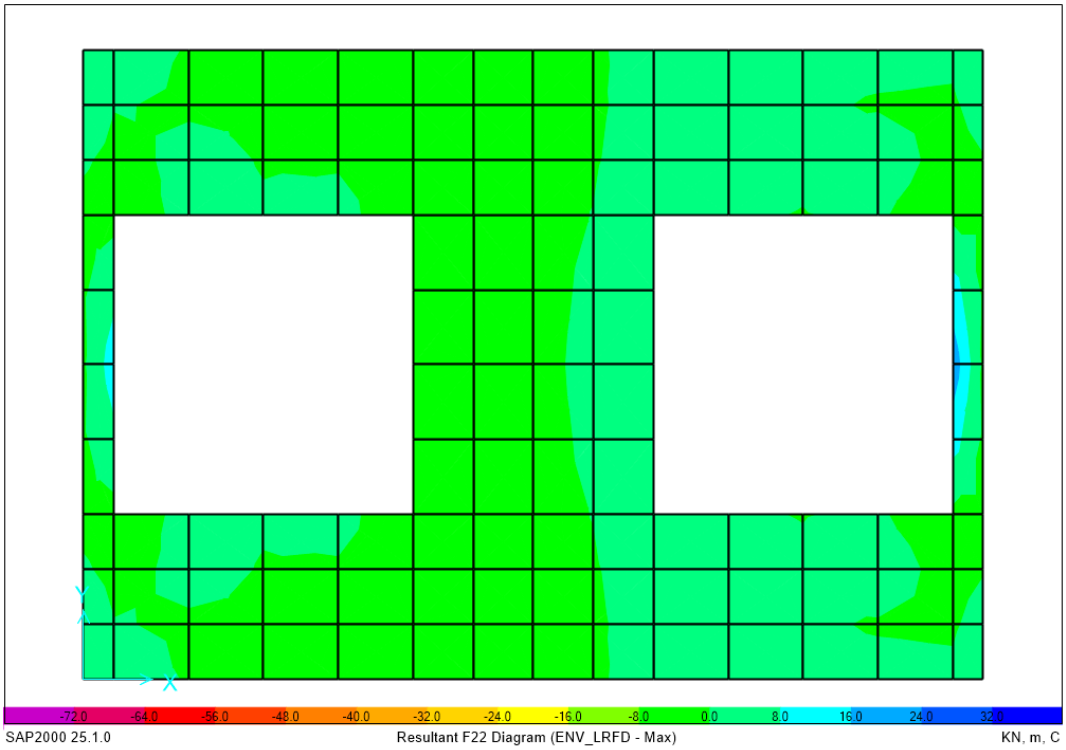
**Losa superior**

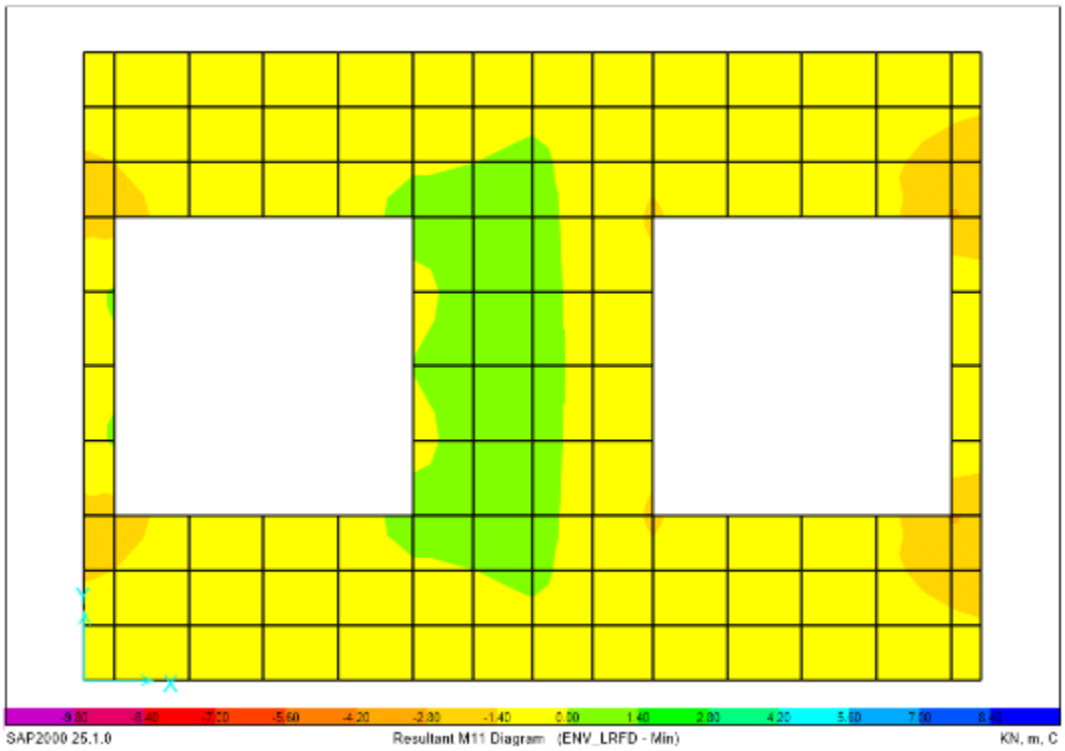
| LOSA SUPERIOR - LRFD RESULTADOS | | | | | |
|---|---|---|---|---|---|
| | $F_{11}$ (kN) | $M_{11}$ (kNm) | $F_{22}$ (kN) | $M_{22}$ (kNm) | Vmax (kN) |
| **ELU (min)** | -74,73 | -4,64 | -34,38 | -2,6 | 0,1 |
| **ELU (max)** | 14,7 | 1,81 | 23,15 | 1,1 | 16,61 |

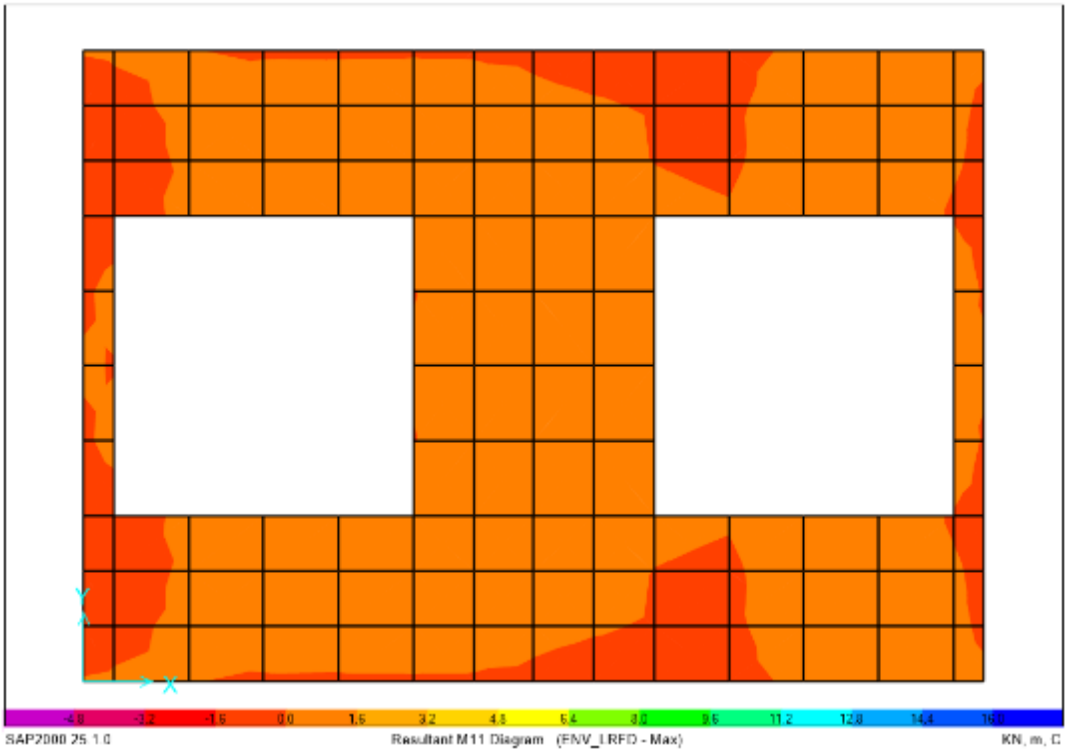


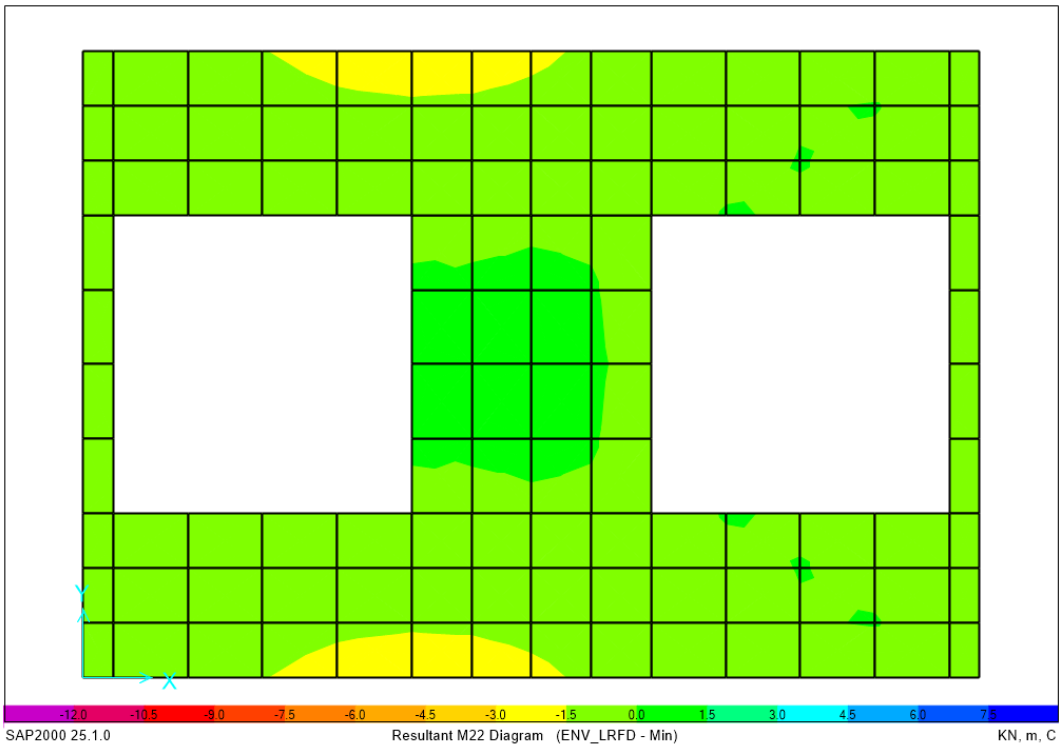



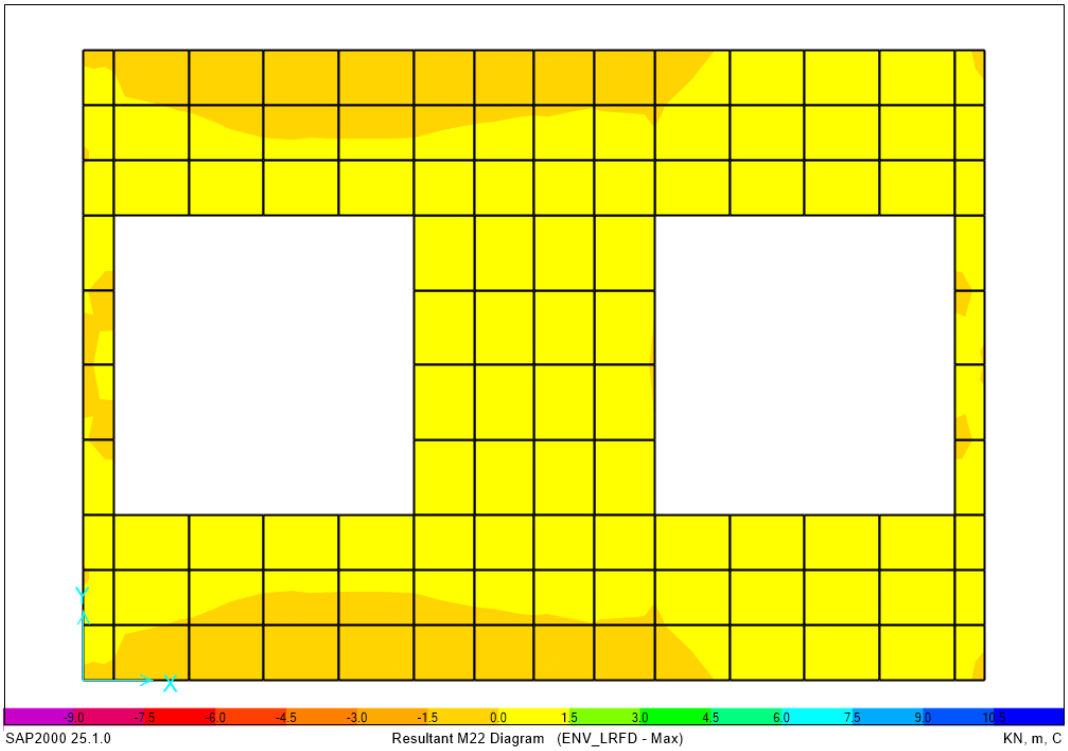

-132 -121 -110 -99 -88 -77 -66 -55 -44 -33 -22 -11 0 11
SAP2000 25.1.0
Resultant F22 Diagram (ENV_LRFD - Min)
KN, m, C

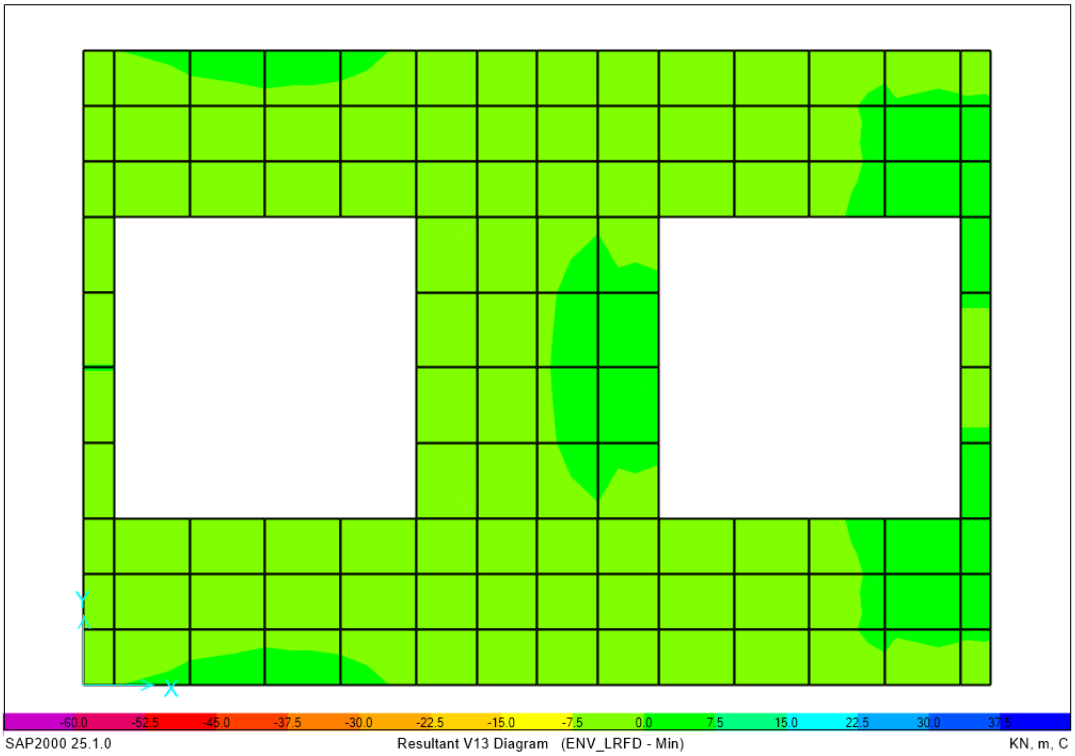

-72.0 -64.0 -56.0 -48.0 -40.0 -32.0 -24.0 -16.0 -8.0 0.0 8.0 16.0 24.0 32.0
SAP2000 25.1.0
Resultant F22 Diagram (ENV_LRFD - Max)
KN, m, C

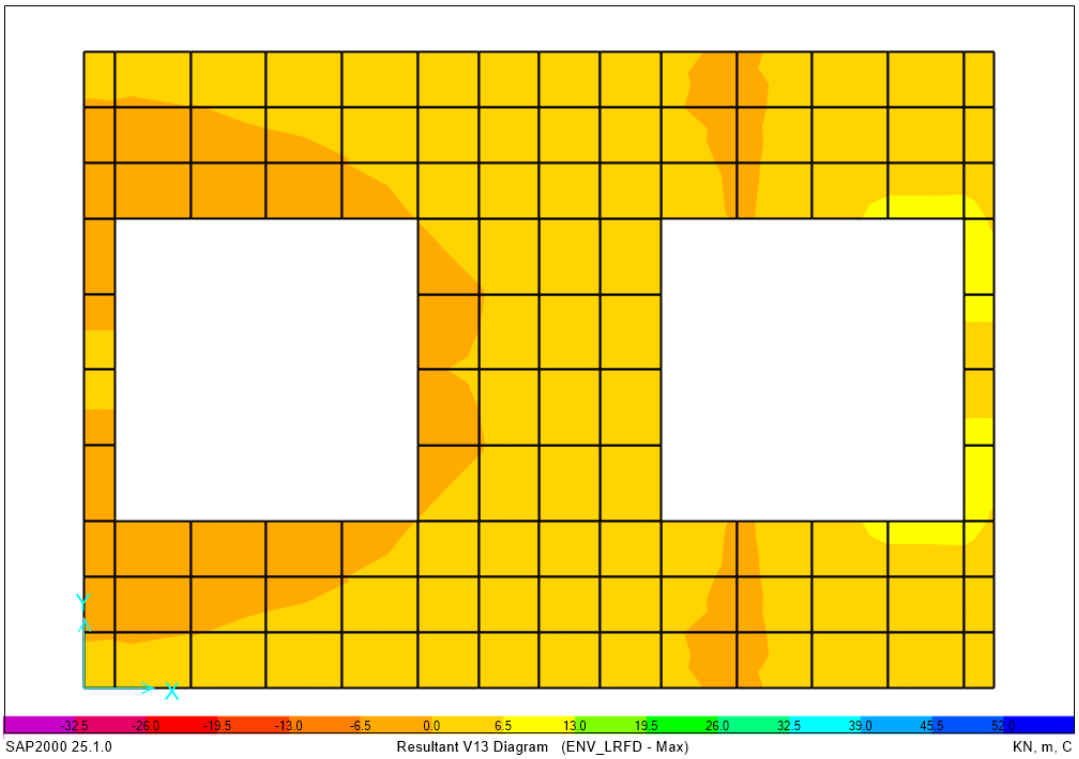

-9.80
-8.40
-7.00
-5.60
-4.20
-2.80
-1.40
0.00
1.40
2.80
4.20
5.60
7.00
8.40
SAP2000 25.1.0
Resultant M11 Diagram (ENV_LRFD - Min)
KN, m, C

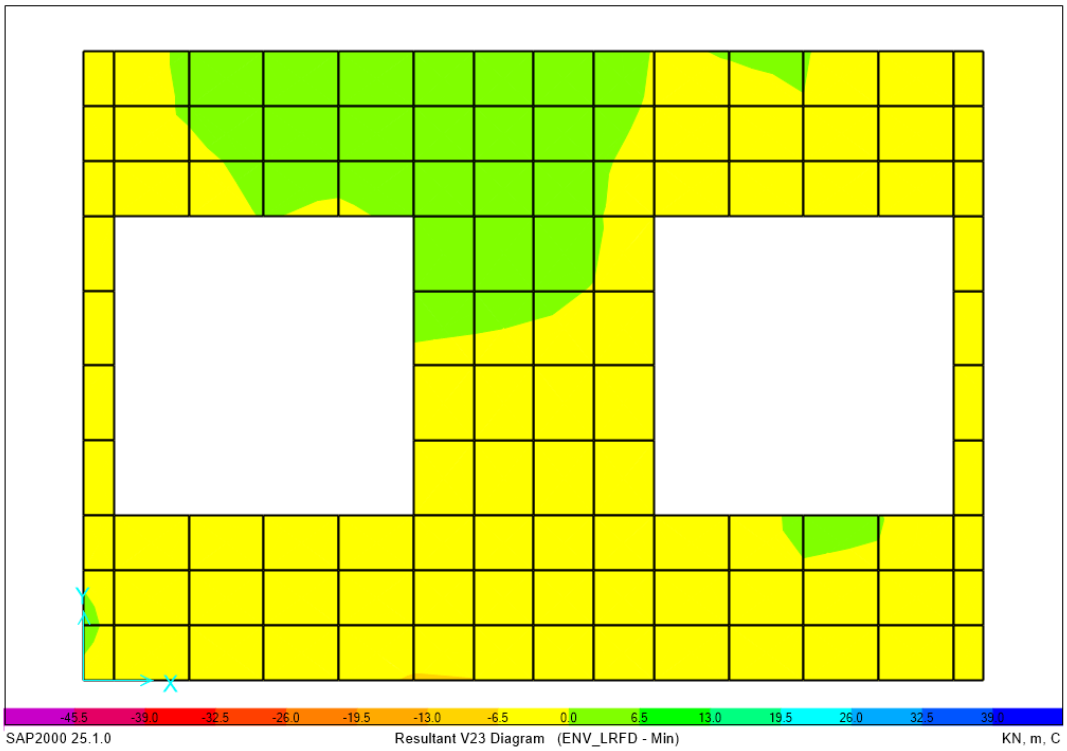

-4.8
-3.2
-1.6
0.0
1.6
3.2
4.8
6.4
8.0
9.6
11.2
12.8
14.4
16.0
SAP2000 25.1.0
Resultant M11 Diagram (ENV_LRFD - Max)
KN, m, C

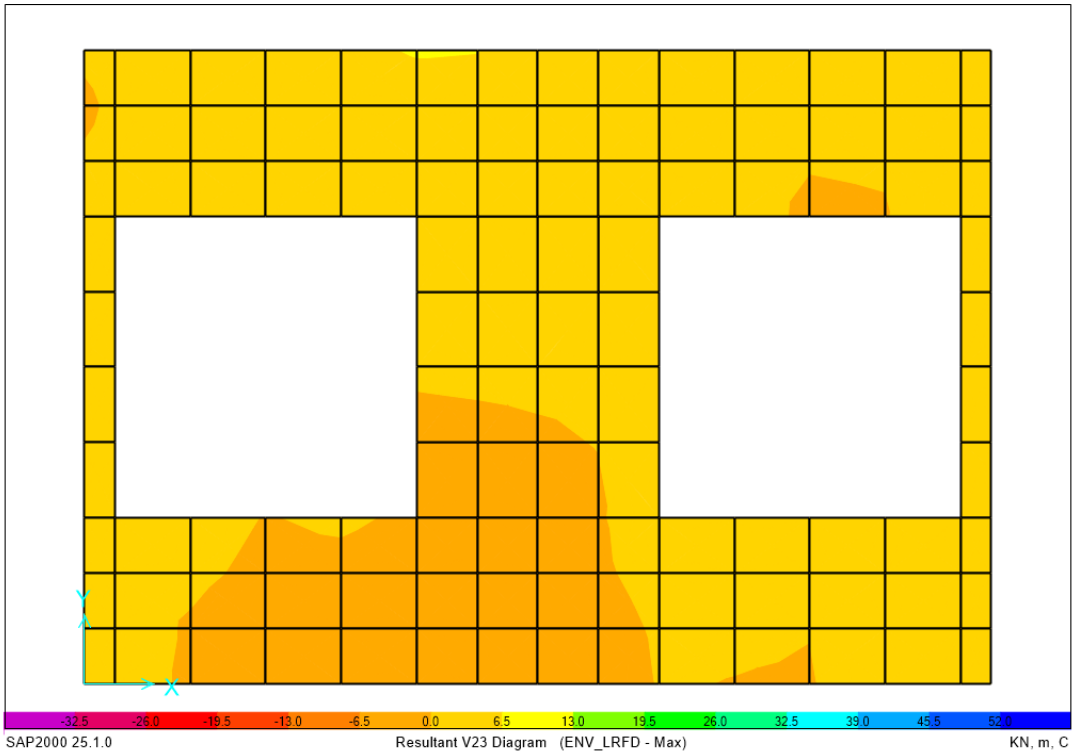

-12.0 -10.5 -9.0 -7.5 -6.0 -4.5 -3.0 -1.5 0.0 1.5 3.0 4.5 6.0 7.5
SAP2000 25.1.0
Resultant M22 Diagram (ENV_LRFD - Min)
KN, m, C


-9.0 -7.5 -6.0 -4.5 -3.0 -1.5 0.0 1.5 3.0 4.5 6.0 7.5 9.0 10.5
SAP2000 25.1.0
Resultant M22 Diagram (ENV_LRFD - Max)
KN, m, C


-60.0 -52.5 -45.0 -37.5 -30.0 -22.5 -15.0 -7.5 0.0 7.5 15.0 22.5 30.0 37.5
SAP2000 25.1.0 Resultant V13 Diagram (ENV_LRFD - Min) KN, m, C


-32.5 -26.0 -19.5 -13.0 -6.5 0.0 6.5 13.0 19.5 26.0 32.5 39.0 45.5 52.0
SAP2000 25.1.0 Resultant V13 Diagram (ENV_LRFD - Max) KN, m, C


-45.5 -39.0 -32.5 -26.0 -19.5 -13.0 -6.5 0.0 6.5 13.0 19.5 26.0 32.5 39.0
SAP2000 25.1.0
Resultant V23 Diagram (ENV_LRFD - Min)
KN, m, C


-32.5 -26.0 -19.5 -13.0 -6.5 0.0 6.5 13.0 19.5 26.0 32.5 39.0 45.5 52.0
SAP2000 25.1.0
Resultant V23 Diagram (ENV_LRFD - Max)
KN, m, C

### 3.9.4 Verificaciones Estado Límite Último (ELU)

**Losa base inferior**

Se propone el siguiente armado:

| ARMADO LOSA BASE INFERIOR | | |
|---|---|---|
| Armadura longitudinal/transversal (cara superior) | Armadura longitudinal/transversal (cara inferior) | Armadura de cortante |
| Ø16@200mm (10.05cm$^2$/m) | Ø16@200mm (10.05cm$^2$/m) | No requerida |

| FLEXURE REINFORCEMENT CALCULATION | | |
|---|---|---|
| REF: EN-1992-1-1 | | |
| **Section inputs & material** | | |
| Flexure design moment | $M_d$ (KNm) | 17 |
| Section width | b (mm) | 1000 |
| Section heigth | h(mm) | 600 |
| Minimum cover | r (mm) | 50 |
| Effective section heigth | d (mm) | 542 |
| Specified compressive strength of concrete | $f_{ck}$(N/mm$^2$) | 25 |
| Coeff. for long term effects in compressive strength (chapter 3.1.6 EN-1992-1-1) | $a_{cc}$ | 0.85 |
| Partial factor for concrete, table 2.1N | $\gamma_c$ | 1.5 |
| Design value of concrete compressive strength $f_{cd} = \alpha_{cc} f_{ck} / \gamma_c$ | $f_{cd}$ (N/mm$^2$) | 14.17 |
| Mean tensile strength (according to table 3.1 EN 1992-1-1) | $f_{ctm}$ (N/mm$^2$) | 2.6 |
| Specified yield strength of reinforcement | $f_{yk}$ (N/mm$^2$) | 500 |
| Partial factor for reinforcing, table 2.1N | $\gamma_s$ | 1.15 |
| Design yield strength of reinforcement | $f_{yd}$ (N/mm$^2$) | 435 |
| Modulus of elasticity of reinforcement | $E_s$ (N/mm$^2$) | 200000 |
| for $f_{ck}$ < 50MPa (3.19) | l | 0.8 |
| for $f_{ck}$ < 50MPa (3.21) | h | 1.00 |
| | $k_1$ | 0.44 |
| | $k_2$ | 1.25 |
| (for $f_{ck}$ < 50MPa )Ultimate concrete strain (table 3.1) | $e_{cu2}$ | 0.0035 |
| Ratio of the redistributed moment to the elastic bending moment | d | 1.00 |
| | $(x/d)_{lim}$ | 0.45 |
| Strain in concrete, max value (table 3.1) | $\varepsilon_c$ (max) | 0.0035 |
| Strain in concrete, min value (table 3.1) | $\varepsilon_c$ (min) | 0.00175 |
| Normalized moment | m | 0.0041 |
| Normalized section capacity as a singly reinforced beam | $m_{lim}$ | 0.2942 |
| | $x_{lim}$(mm) | 242.8160 |
| **Reinforcement** | | |
| | If m<$m_{lim}$: | **APPLIED** |
| Normalized steel ratio | w | 0.00409 |
| Longitudinal reinforcement area in tensile | $A_s$ (cm$^2$) | 0.723 |
| | If m>$m_{lim}$: | **NOT APPLIED** |
| | $w_{lim}$ | 0.3584 |
| Depth to the compression steel, measured from the concrete compression face | d´ (mm) | 58 |
| | w´ | -0.324852637 |
| | w | 0.033547363 |
| Stress in the compression steel | $f_s$´ (N/mm$^2$) | 434.7826087 |
| Longitudinal reinforcement area in compression | $A_s$´(cm$^2$) (up for $M_d$+) | Not required |
| Longitudinal reinforcement area in tensile | $A_s$ (cm$^2$) (bottom for $M_d$+) | 5.92 |

| | | |
|---|---|---|
| OVERALL Required Md | $A_s'$ ($cm^2$) (up for $M_d$ +) | 0.000 |
| OVERALL Required Md | $A_s$ ($cm^2$)(bottom for $M_d$ +) | 0.723 |
| The tensile is in both faces | T (kN) | 10 |
| Shear effort (6.2.3 (7), EN-1992-1-1) | $V_E$ (kN) | 0 |
| Reinf. in each face | $A_s$ ($cm^2$) | 0.115 |
| Total necessary reinf. In top face | $A_s$ ($cm^2$)(TOTAL) | **0.12** |
| Total necessary reinf. In low face (tensile face) | $A_s$ ($cm^2$)(TOTAL) | **0.84** |

**Disposed reinforcement:**

| | | |
|---|---|---|
| Diameter of bar | ϕ (mm) | 16 |
| Bar spacing | s (m) | 200 |
| Nº of reinf.layers | n | 1 |
| Area provided | A ($cm^2$) | 10.053 |
| | additional reinforcement | |
| Diameter of bar | ϕ (mm) | 0 |
| Bar spacing | s (m) | 200 |
| Area provided | A ($cm^2$) | 0.000 |
| | $A_{total}$ ($cm^2$) | 10.053 |
| | **OK Flexure** | **8%** |
| | - | - |
| - | - | - |

**Minimum reinforcement EN-1992-1-1**

| | | |
|---|---|---|
| | Section type | SLAB/FOUNDATION |
| | minimum ratio | **0.001352** |
| Minimum reinforcement for each face | $As_{min}$ ($cm^2$) | 7.328 |
| - | - | - |
| Reinforcement provided | $A_{total}$ ($cm^2$) | **10.05** |
| | **OK Minimum reinforcement** | **73%** |

**Maximum reinforcement EN-1992-1-1**

| | | |
|---|---|---|
| | maximum ratio | **0.040** |
| | $As_{max}$ ($cm^2$) | 240 |
| | **OK maximum reinforcement** | **4%** |
| | $s_{max}$ (mm) | 400 |
| | | **OK** |

| SHEAR REINFORCEMENT CALCULATION | | | |
|---|---|---|---|
| | | | EN 1992-1 AND EN 1992-2 |
| **Geometry and materials** | | | |
| Overall depth of the cross section | $h$ | [m] | 0.60 |
| Distance from the tension fiber to the centroid of the tensile reinforcement | $d'$ | [m] | 0.05 |
| Effective depth | $d$ | [m] | 0.55 |
| Smallest width of the cross section in the tensile area | $b_w$ | [m] | 1.00 |
| Number of grouted metal ducts in the web | $N_{ducts}$ | | 0 |
| Diamenter of the duct | $\phi_{duct}$ | [mm] | 0 |
| Nominal web thickness considering the PT ducts | $b_{w,nom}$ | [m] | 1.00 |
| Characteristic compressive cylinder strength of concrete at 28 days | $f_{ck}$ | [MPa] | 25 |
| Partial factor for concrete | $\gamma_c$ | | 1.2 |
| Characteristic yield strength of shear reinforcement | $f_{ywk}$ | [MPa] | 500 |
| Partial factor for reinforcing steel | $\gamma_s$ | | 1 |
| Area of tensile reinforcement | $A_{sl}$ | [$cm^2$] | 10.05 |
| Area of concrete cross section | $A_c$ | [$m^2$] | 0.60 |
| **Forces** | | | |
| Axial force in the cross section due to loading or the acing effect of prestressing ($N_{Ed}$ > 0 for compression) | $N_{Ed}$ | [kN] | -12.0 |
| Design value of the applied shear force | $V_{Ed}$ | [kN] | 64.0 |
| **Members not requiring shear reinforcement** | | | |
| | $k$ | | 1.6 |
| | $\rho_l$ | | 0.0018 |
| | $\sigma_{cp}$ | [MPa] | -0.02 |
| | $C_{Rd,c}$ | | 0.15 |
| | $v_{min}$ | [MPa] | 0.36 |
| | $k_1$ | | 0.15 |
| Design value for the shear resistance | **$V_{Rd,c}$** | **[kN]** | **217.8** |

## Muros

Se propone el siguiente armado:

| ARMADO MUROS | | |
|---|---|---|
| Armadura longitudinal/transversal (cara externa) | Armadura longitudinal/transversal (cara interna) | Armadura de cortante |
| Ø12@200mm (5,65cm²/m) | Ø12@200mm (5,65cm²/m) | No requiere armado a cortante |

| FLEXURE REINFORCEMENT CALCULATION | | |
|---|---|---|
| REF: EN-1992-1-1 | | |
| **Section inputs & material** | | |
| Flexure design moment | $M_d$ (KNm) | 13 |
| Section width | b (mm) | 1000 |
| Section heigth | h(mm) | 300 |
| Minimum cover | r (mm) | 50 |
| Effective section heigth | d (mm) | 244 |
| Specified compressive strength of concrete | $f_{ck}$(N/mm²) | 25 |
| Coeff. for long term effects in compressive strength (chapter 3.1.6 EN-1992-1-1) | $a_{cc}$ | 0.85 |
| Partial factor for concrete, table 2.1N | $\gamma_c$ | 1.5 |
| Design value of concrete compressive strength $f_{cd} = \alpha_{cc} f_{ck} / \gamma_C$ | $f_{cd}$ (N/mm²) | 14.17 |
| Mean tensile strength (according to table 3.1 EN 1992-1-1) | $f_{ctm}$ (N/mm²) | 2.6 |
| Specified yield strength of reinforcement | $f_{yk}$ (N/mm²) | 500 |
| Partial factor for reinforcing, table 2.1N | $\gamma_s$ | 1.15 |
| Design yield strength of reinforcement | $f_{yd}$ (N/mm²) | 435 |
| Modulus of elasticity of reinforcement | $E_s$ (N/mm²) | 200000 |
| for $f_{ck}$ < 50MPa (3.19) | l | 0.8 |
| for $f_{ck}$ < 50MPa (3.21) | h | 1.00 |
| | $k_1$ | 0.44 |
| | $k_2$ | 1.25 |
| (for $f_{ck}$ < 50MPa )Ultimate concrete strain (table 3.1) | $e_{cu2}$ | 0.0035 |
| Ratio of the redistributed moment to the elastic bending moment | d | 1.00 |
| | $(x/d)_{lim}$ | 0.45 |
| Strain in concrete, max value (table 3.1) | $\varepsilon_c$ (max) | 0.0035 |
| Strain in concrete, min value (table 3.1) | $\varepsilon_c$ (min) | 0.00175 |
| Normalized moment | m | 0.0154 |
| Normalized section capacity as a singly reinforced beam | $m_{lim}$ | 0.2942 |
| | $x_{lim}$(mm) | 109.3120 |
| **Reinforcement** | | |
| | If m<$m_{lim}$: | **APPLIED** |
| Normalized steel ratio | w | 0.01553 |
| Longitudinal reinforcement area in tensile | $A_s$ (cm²) | 1.235 |
| | If m>$m_{lim}$: | **NOT APPLIED** |
| | $w_{lim}$ | 0.3584 |
| Depth to the compression steel, measured from the concrete compression face | d´ (mm) | 56 |
| | w´ | -0.361796719 |
| | w | -0.003396719 |
| Stress in the compression steel | $f_s$´ (N/mm²) | 341.3934426 |
| Longitudinal reinforcement area in compression | $A_s$´(cm²) (up for $M_d$+) | Not required |
| Longitudinal reinforcement area in tensile | $A_s$ (cm²) (bottom for $M_d$+) | -0.27 |

| | | |
|---|---|---|
| OVERALL Required Md | $A_s'$ ($cm^2$) (up for $M_d$ +) | 0.000 |
| OVERALL Required Md | $A_s$ ($cm^2$)(bottom for $M_d$ +) | 1.235 |
| The tensile is in both faces | T (kN) | 30 |
| Shear effort (6.2.3 (7), EN-1992-1-1) | $V_E$ (kN) | 0 |
| Reinf. in each face | $A_s$ ($cm^2$) | 0.345 |
| Total necessary reinf. In top face | $A_s$ ($cm^2$)(TOTAL) | **0.35** |
| Total necessary reinf. In low face (tensile face) | $A_s$ ($cm^2$)(TOTAL) | **1.58** |

**Disposed reinforcement:**

| | | |
|---|---|---|
| Diameter of bar | ϕ (mm) | 12 |
| Bar spacing | s (m) | 200 |
| Nº of reinf.layers | n | 1 |
| Area provided | A ($cm^2$) | 5.655 |
| | additional reinforcement | |
| Diameter of bar | ϕ (mm) | 0 |
| Bar spacing | s (m) | 200 |
| Area provided | A ($cm^2$) | 0.000 |
| | $A_{total}$ ($cm^2$) | 5.655 |
| | **OK Flexure** | **28%** |
| | - | - |
| - | - | - |

**Minimum reinforcement EN-1992-1-1**

| | | |
|---|---|---|
| | Section type | WALL (horizontal) |
| | minimum ratio | **0.001600** |
| Minimum reinforcement for each face | $As_{min}$ ($cm^2$) | 3.904 |
| - | - | - |
| Reinforcement provided | $A_{total}$ ($cm^2$) | **5.65** |
| | **OK Minimum reinforcement** | **69%** |

**Maximum reinforcement EN-1992-1-1**

| | | |
|---|---|---|
| | maximum ratio | **0.040** |
| | $As_{max}$ ($cm^2$) | 120 |
| | **OK maximum reinforcement** | **5%** |
| | $s_{max}$ (mm) | 400 |
| | | **OK** |

| SHEAR REINFORCEMENT CALCULATION | | | |
|---|---|---|---|
| | | | EN 1992-1 AND EN 1992-2 |
| **Geometry and materials** | | | |
| Overall depth of the cross section | h | [m] | 0.30 |
| Distance from the tension fiber to the centroid of the tensile reinforcement | d' | [m] | 0.05 |
| Effective depth | d | [m] | 0.25 |
| Smallest width of the cross section in the tensile area | $b_w$ | [m] | 1.00 |
| Number of grouted metal ducts in the web | $N_{ducts}$ | | 0 |
| Diamenter of the duct | $\phi_{duct}$ | [mm] | 0 |
| Nominal web thickness considering the PT ducts | $b_{w,nom}$ | [m] | 1.00 |
| Characteristic compressive cylinder strength of concrete at 28 days | $f_{ck}$ | [MPa] | 25 |
| Partial factor for concrete | $\gamma_c$ | | 1.2 |
| Characteristic yield strength of shear reinforcement | $f_{ywk}$ | [MPa] | 500 |
| Partial factor for reinforcing steel | $\gamma_s$ | | 1 |
| Area of tensile reinforcement | $A_{sl}$ | [$cm^2$] | 5.65 |
| Area of concrete cross section | $A_c$ | [$m^2$] | 0.30 |
| **Forces** | | | |
| Axial force in the cross section due to loading or the acing effect of prestressing ($N_{Ed}$ > 0 for compression) | $N_{Ed}$ | [kN] | -30.0 |
| Design value of the applied shear force | $V_{Ed}$ | [kN] | 35.0 |
| **Members not requiring shear reinforcement** | | | |
| | k | | 1.9 |
| | $\rho_l$ | | 0.0023 |
| | $\sigma_{cp}$ | [MPa] | -0.10 |
| | $C_{Rd,c}$ | | 0.15 |
| | $v_{min}$ | [MPa] | 0.46 |
| | $k_1$ | | 0.15 |
| Design value for the shear resistance | **$V_{Rd,c}$** | **[kN]** | **122.8** |

## Losa superior

| ARMADO LOSA SUPERIOR | | |
|---|---|---|
| Armadura longitudinal/transversal (cara externa) | Armadura longitudinal/transversal (cara interna) | Armadura de cortante |
| Ø12@200mm (5,65cm²/m) | Ø12@200mm (5,65cm²/m) | No requiere armado a cortante |

| FLEXURE REINFORCEMENT CALCULATION | | |
|---|---|---|
| REF: EN-1992-1-1 | | |
| **Section inputs & material** | | |
| Flexure design moment | $M_d$ (KNm) | 5 |
| Section width | b (mm) | 1000 |
| Section heigth | h(mm) | 300 |
| Minimum cover | r (mm) | 50 |
| Effective section heigth | d (mm) | 244 |
| Specified compressive strength of concrete | $f_{ck}$(N/mm²) | 25 |
| Coeff. for long term effects in compressive strength (chapter 3.1.6 EN-1992-1-1) | $a_{cc}$ | 0.85 |
| Partial factor for concrete, table 2.1N | $\gamma_c$ | 1.5 |
| Design value of concrete compressive strength $f_{cd} = \alpha_{cc} f_{ck} / \gamma_C$ | $f_{cd}$ (N/mm²) | 14.17 |
| Mean tensile strength (according to table 3.1 EN 1992-1-1) | $f_{ctm}$ (N/mm²) | 2.6 |
| Specified yield strength of reinforcement | $f_{yk}$ (N/mm²) | 500 |
| Partial factor for reinforcing, table 2.1N | $\gamma_s$ | 1.15 |
| Design yield strength of reinforcement | $f_{yd}$ (N/mm²) | 435 |
| Modulus of elasticity of reinforcement | $E_s$ (N/mm²) | 200000 |
| for $f_{ck}$ < 50MPa (3.19) | l | 0.8 |
| for $f_{ck}$ < 50MPa (3.21) | h | 1.00 |
| | $k_1$ | 0.44 |
| | $k_2$ | 1.25 |
| (for $f_{ck}$ < 50MPa )Ultimate concrete strain (table 3.1) | $e_{cu2}$ | 0.0035 |
| Ratio of the redistributed moment to the elastic bending moment | d | 1.00 |
| | $(x/d)_{lim}$ | 0.45 |
| Strain in concrete, max value (table 3.1) | $\varepsilon_c$ (max) | 0.0035 |
| Strain in concrete, min value (table 3.1) | $\varepsilon_c$ (min) | 0.00175 |
| Normalized moment | m | 0.0059 |
| Normalized section capacity as a singly reinforced beam | $m_{lim}$ | 0.2942 |
| | $x_{lim}$(mm) | 109.3120 |
| **Reinforcement** | | |
| | If m<$m_{lim}$: | **APPLIED** |
| Normalized steel ratio | w | 0.00595 |
| Longitudinal reinforcement area in tensile | $A_s$ (cm²) | 0.473 |
| | If m>$m_{lim}$: | **NOT APPLIED** |
| | $w_{lim}$ | 0.3584 |
| Depth to the compression steel, measured from the concrete compression face | d´ (mm) | 56 |
| | w´ | -0.374107189 |
| | w | -0.015707189 |
| Stress in the compression steel | $f_s$´ (N/mm²) | 341.3934426 |
| Longitudinal reinforcement area in compression | $A_s$´(cm²) (up for $M_d$+) | Not required |
| Longitudinal reinforcement area in tensile | $A_s$ (cm²) (bottom for $M_d$+) | -1.25 |

| | | |
|---|---|---|
| OVERALL Required Md | $A_s'$ ($cm^2$) (up for $M_d$ +) | 0.000 |
| OVERALL Required Md | $A_s$ ($cm^2$)(bottom for $M_d$ +) | 0.473 |
| The tensile is in both faces | T (kN) | 15 |
| Shear effort (6.2.3 (7), EN-1992-1-1) | $V_E$ (kN) | 0 |
| Reinf. in each face | $A_s$ ($cm^2$) | 0.173 |
| Total necessary reinf. In top face | $A_s$ ($cm^2$)(TOTAL) | **0.17** |
| Total necessary reinf. In low face (tensile face) | $A_s$ ($cm^2$)(TOTAL) | **0.65** |

**Disposed reinforcement:**

| | | |
|---|---|---|
| Diameter of bar | ϕ (mm) | 12 |
| Bar spacing | s (m) | 200 |
| Nº of reinf.layers | n | 1 |
| Area provided | A ($cm^2$) | 5.655 |
| | additional reinforcement | |
| Diameter of bar | ϕ (mm) | 0 |
| Bar spacing | s (m) | 200 |
| Area provided | A ($cm^2$) | 0.000 |
| | $A_{total}$ ($cm^2$) | 5.655 |
| | **OK Flexure** | **11%** |
| | - | - |
| - | - | - |

**Minimum reinforcement EN-1992-1-1**

| | | |
|---|---|---|
| | Section type | SLAB/FOUNDATION |
| | minimum ratio | **0.001352** |
| Minimum reinforcement for each face | $As_{min}$ ($cm^2$) | 3.299 |
| - | - | - |
| Reinforcement provided | $A_{total}$ ($cm^2$) | **5.65** |
| | **OK Minimum reinforcement** | **58%** |

**Maximum reinforcement EN-1992-1-1**

| | | |
|---|---|---|
| | maximum ratio | **0.040** |
| | $As_{max}$ ($cm^2$) | 120 |
| | **OK maximum reinforcement** | **5%** |
| | $s_{max}$ (mm) | 400 |
| | | **OK** |

| SHEAR REINFORCEMENT CALCULATION | | | |
|---|---|---|---|
| | | | EN 1992-1 AND EN 1992-2 |
| **Geometry and materials** | | | |
| Overall depth of the cross section | h | [m] | 0.30 |
| Distance from the tension fiber to the centroid of the tensile reinforcement | d' | [m] | 0.05 |
| Effective depth | d | [m] | 0.25 |
| Smallest width of the cross section in the tensile area | $b_w$ | [m] | 1.00 |
| Number of grouted metal ducts in the web | $N_{ducts}$ | | 0 |
| Diamenter of the duct | $\phi_{duct}$ | [mm] | 0 |
| Nominal web thickness considering the PT ducts | $b_{w,nom}$ | [m] | 1.00 |
| Characteristic compressive cylinder strength of concrete at 28 days | $f_{ck}$ | [MPa] | 25 |
| Partial factor for concrete | $\gamma_c$ | | 1.2 |
| Characteristic yield strength of shear reinforcement | $f_{ywk}$ | [MPa] | 500 |
| Partial factor for reinforcing steel | $\gamma_s$ | | 1 |
| Area of tensile reinforcement | $A_{sl}$ | [$cm^2$] | 5.65 |
| Area of concrete cross section | $A_c$ | [$m^2$] | 0.30 |
| **Forces** | | | |
| Axial force in the cross section due to loading or the acing effect of prestressing ($N_{Ed}$ > 0 for compression) | $N_{Ed}$ | [kN] | -23.0 |
| Design value of the applied shear force | $V_{Ed}$ | [kN] | 17.0 |
| **Members not requiring shear reinforcement** | | | |
| | k | | 1.9 |
| | $\rho_l$ | | 0.0023 |
| | $\sigma_{cp}$ | [MPa] | -0.08 |
| | $C_{Rd,c}$ | | 0.15 |
| | $v_{min}$ | [MPa] | 0.46 |
| | $k_1$ | | 0.15 |
| Design value for the shear resistance | **$V_{Rd,c}$** | **[kN]** | **123.7** |

### 3.9.5 Verificación Estado Límite Servicio (ELS)

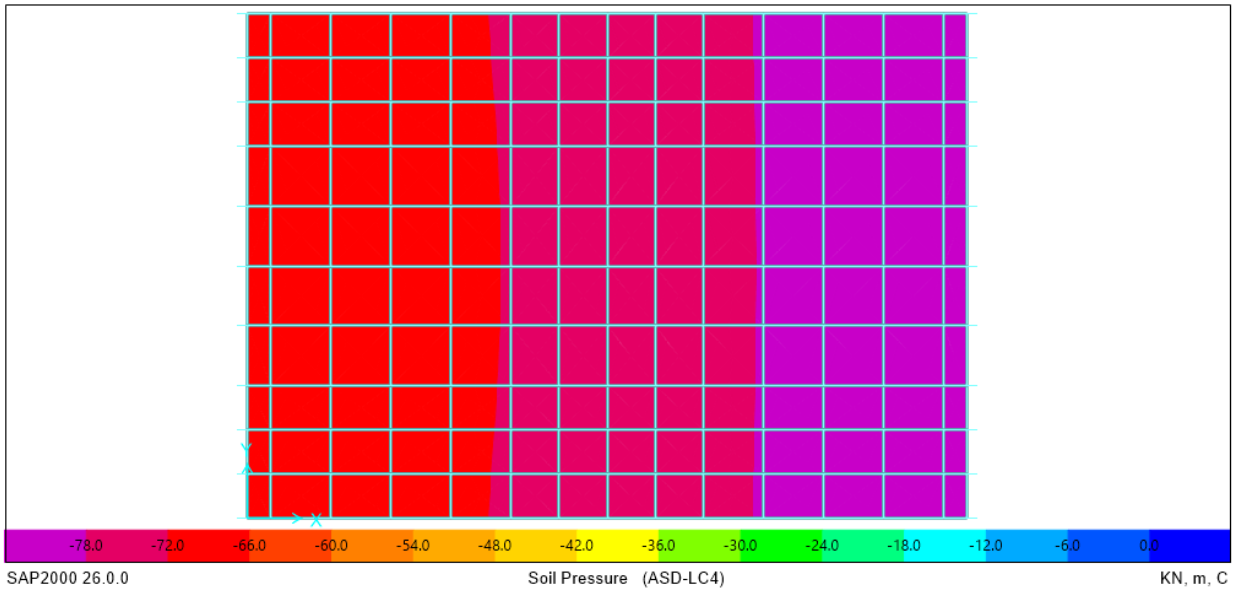
#### Comprobación abertura máxima de fisura

Se ha realizado una comprobación del máximo momento de fisuración por cada sección. A continuación, se proporciona un resumen del momento máximo resistente y del momento solicitado por tipo de sección:

| COMPROBACIÓN A FISURACIÓN | | |
|---|---|---|
| **Sección** | **$M_d$ (kNm)** | **$M_R$ (kNm)** |
| Losa base inferior | 11,8 | 192,60 |
| Muros | 7,8 | 48,15 |
| Losa superior | 1,6 | 48,15 |

#### Tensión máxima transmitida al terreno

La tensión máxima transmitida al terreno es de 78k N/m².


-78.0
-72.0
-66.0
-60.0
-54.0
-48.0
-42.0
-36.0
-30.0
-24.0
-18.0
-12.0
-6.0
0.0
SAP2000 26.0.0
Soil Pressure (ASD-LC4)
KN, m, C

## 3.10 Modelo de cálculo. Arqueta de rotura

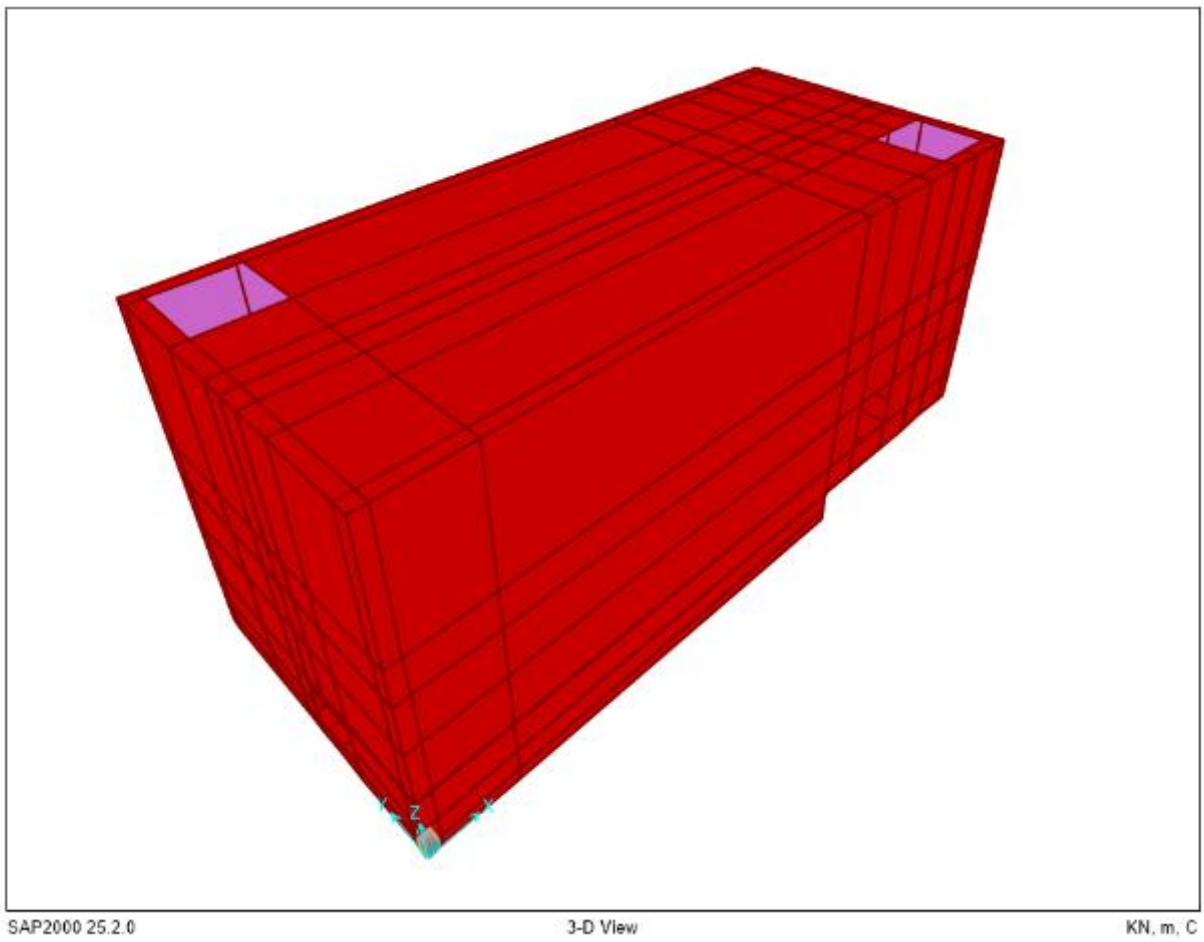
El cálculo estructural se realiza acorde al método global de análisis utilizado para cálculo de fuerzas y momentos internos de los miembros, mediante un modelo tridimensional, con el software de diseño estructural SAP2000 v25.1.0.

Este software utiliza el método de análisis elástico que puede usarse en todos los casos. El programa se basa en técnicas de cálculo matricial y elementos finitos bajo las habituales hipótesis de elasticidad lineal:

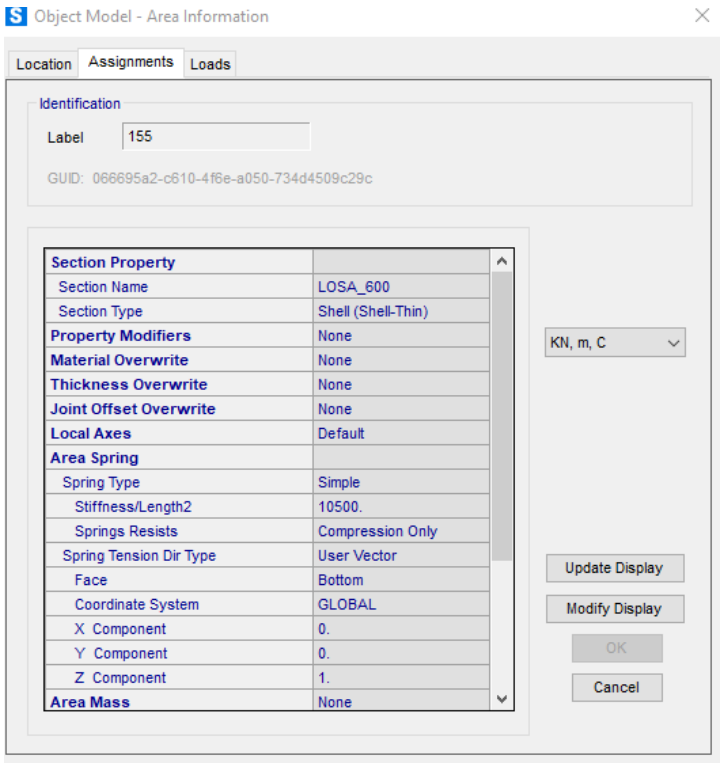
- Proporcionalidad entre tensiones y deformaciones.
- Compatibilidad de elementos estructurales.
- Balance estático local y global de cada una de las partes de la estructura

### 3.10.1 Geometría

Los muros y losas que forman la arqueta se representan mediante elementos tipo «Shell» de distintos espesores.



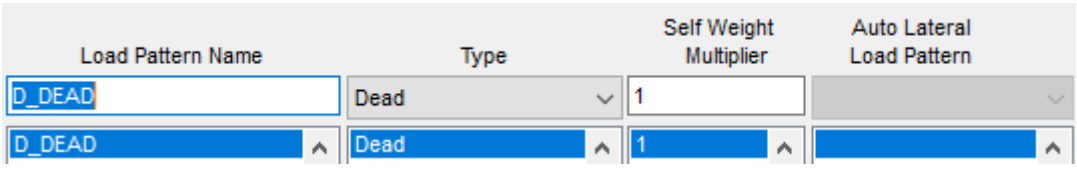
El módulo de balasto considerado según el terreno en la cimentación es de 10500 kN/m$^3$.



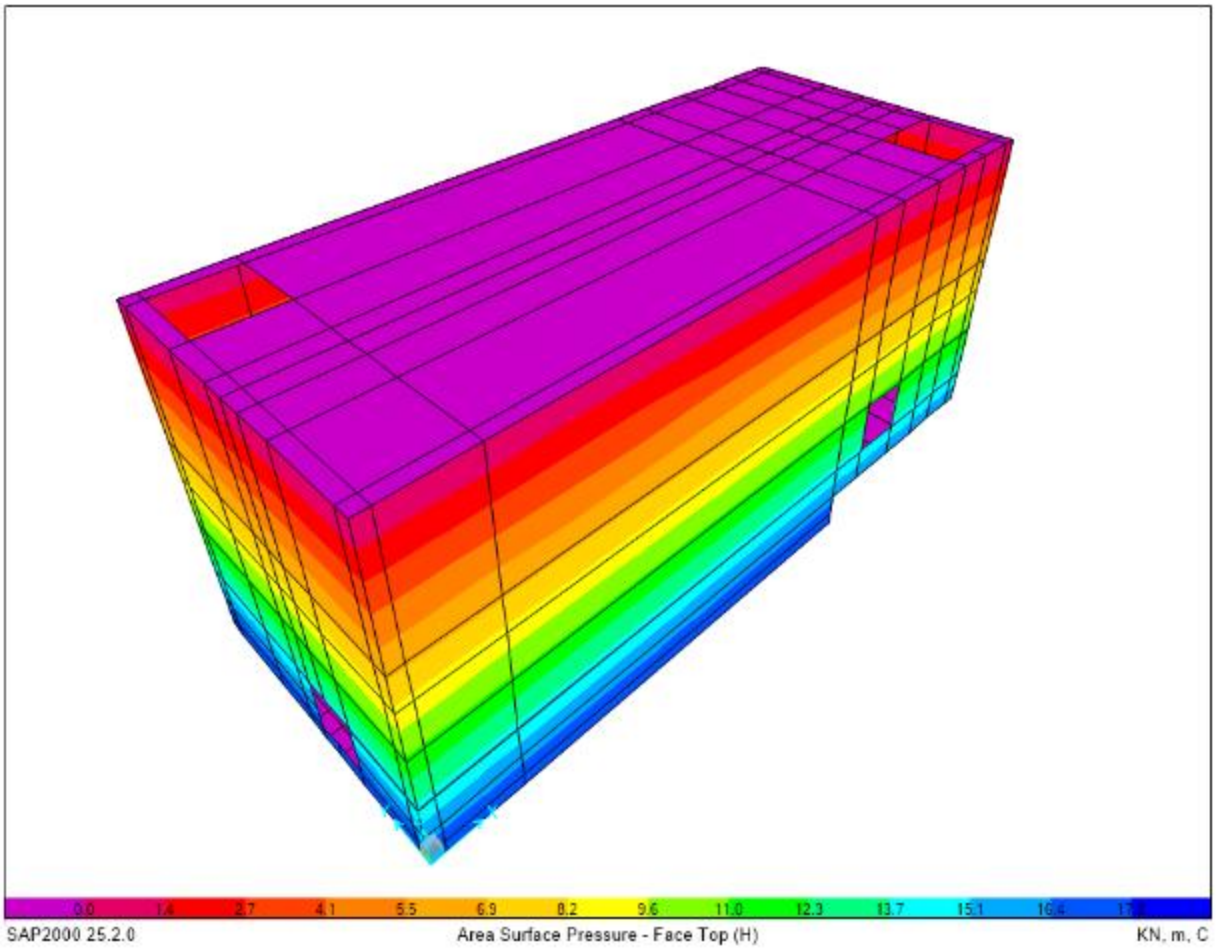

### 3.10.2 Acciones de cálculo en el modelo

**Peso propio**

El peso propio de los elementos (muros y losas de hormigón) SAP2000 lo introduce directamente con las definiciones que se han hecho de las propiedades de los elementos y los materiales. En el programa esta acción se denomina DEAD.



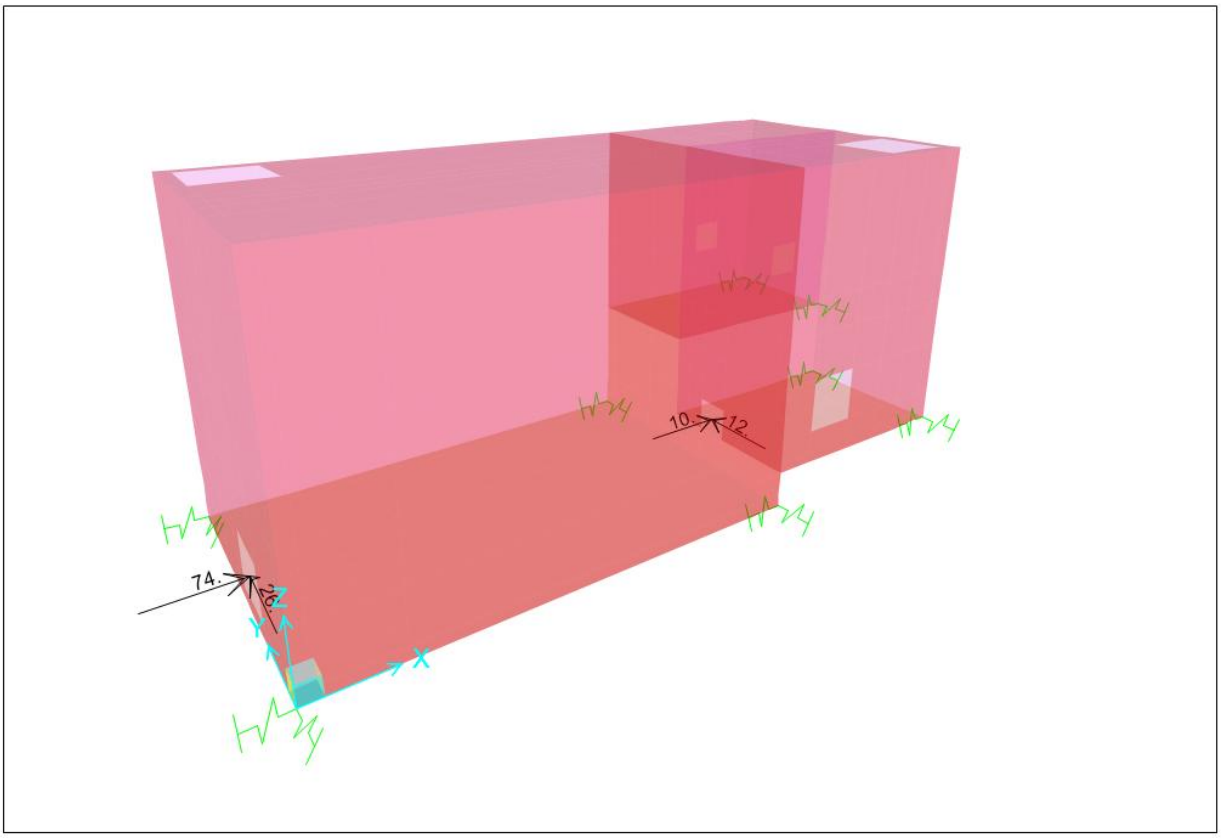
**Empuje del terreno**



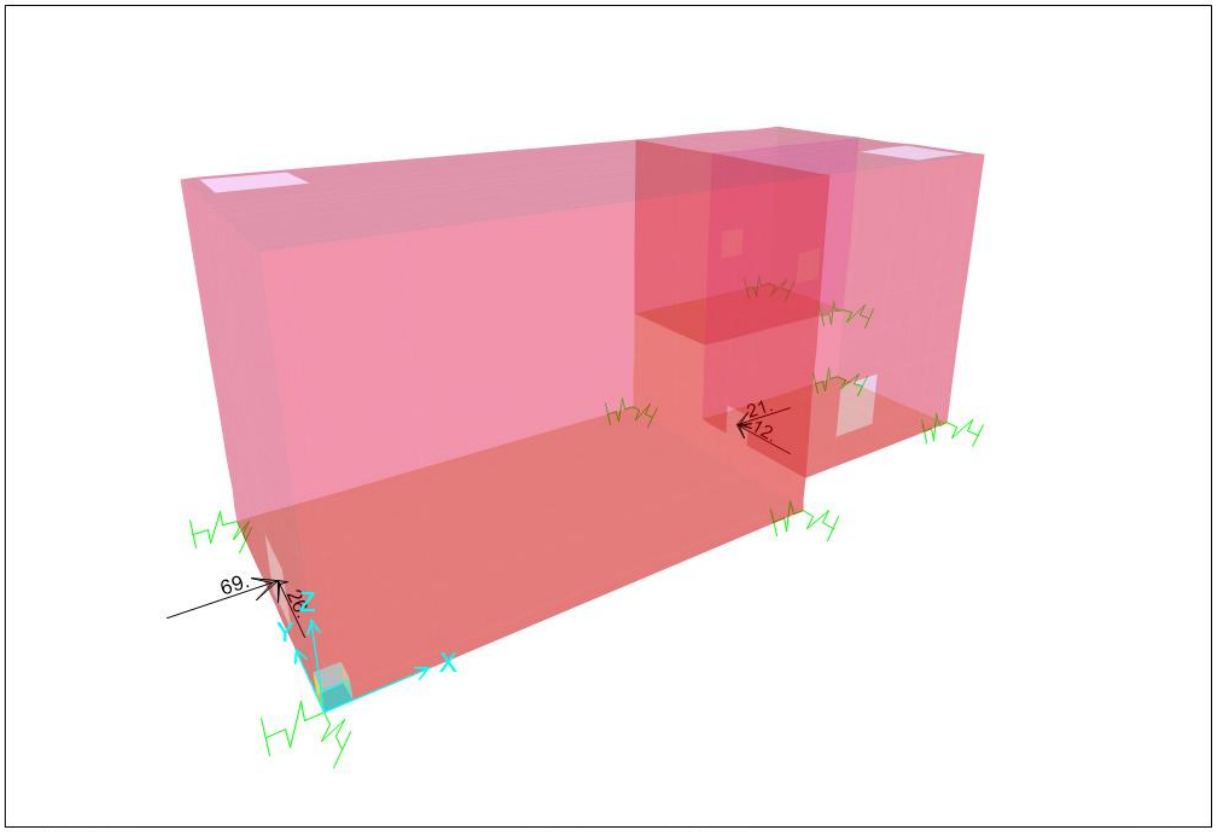

**Sobrecargas de uso**

Para la representación de las reacciones del uso de las tuberías se han definido dos casos de carga: L_normal y L_bypass.

Para la obtención de estas reacciones se realiza un modelo simplificado de la tubería apoyada en las paredes de la arqueta, sometida a las cargas indicadas en el apartado de cargas, obteniendo las reacciones que deberán soportar la arqueta.




SAP2000 25.2.0 Joint Loads (L_normal) (As Defined) KN, m, C



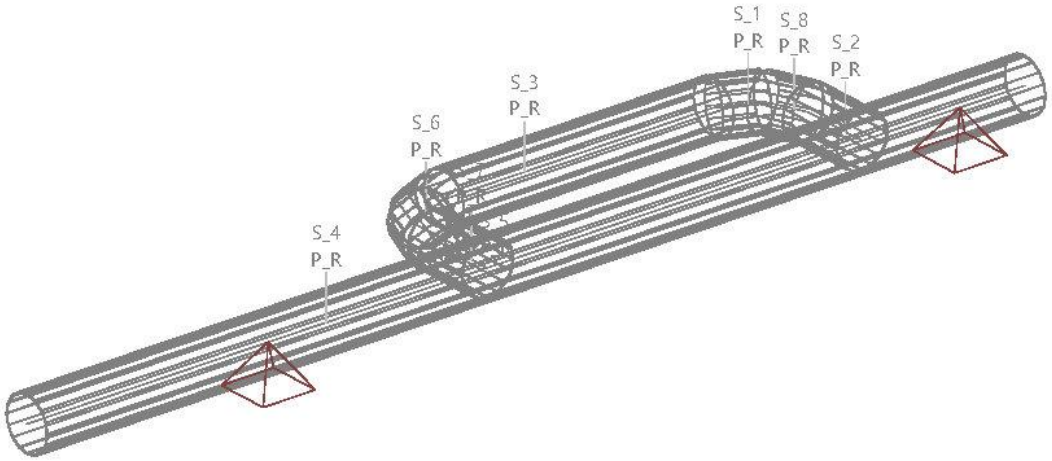

SAP2000 25.2.0 Joint Loads (L_bypass) (As Defined) KN, m, C

| Tías | Página 1 |
|---|---|
| Soportes tuberías 01 | 08.08.24, 17:29 |
| PROES S.A., 28020 Madrid . | Statik-9 - Rel. 241 (0) |

Estructura



Estructura

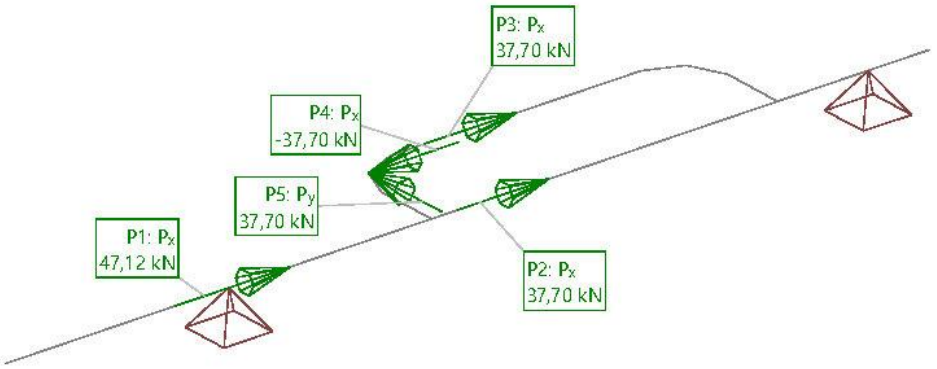



Nr.:

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| Tías | Página 2 |
|---|---|
| Soportes tuberías 01 | 08.08.24, 17:29 |
| PROES S.A., 28020 Madrid . | Statik-9 - Rel. 241 (0) |

Hipótesis de carga FNormal: Funcio. normal




**Hipótesis de carga 'FNormal': Funcio. normal**

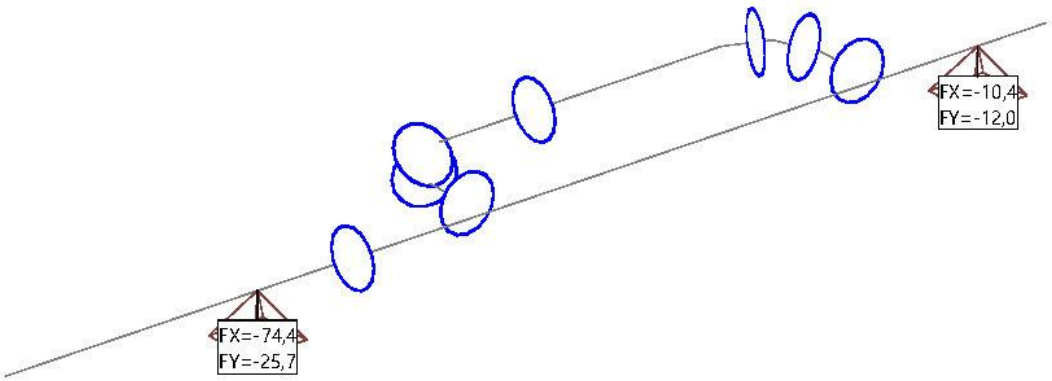
**Cargas puntuales: Fuerzas y momentos**

| Nombre | Tipo | P [kN] | M [kNm] | $X_{Suma}$ [kN] | $Y_{Suma}$ [kN] | $Z_{Suma}$ [kN] |
|---|---|---|---|---|---|---|
| P1 | X Global Fuerza en barra | 47,12 | | 47,12 | 0 | 0 |
| P2 | X Global Fuerza en barra | 37,70 | | 37,70 | 0 | 0 |
| P3 | X Global Fuerza en barra | 37,70 | | 37,70 | 0 | 0 |
| P4 | X Global Fuerza en barra | -37,70 | | -37,70 | 0 | 0 |
| P5 | Y Global Fuerza en barra | 37,70 | | 0 | 37,70 | 0 |

**Suma de cargas**

| | $X_{Suma}$ [kN] | $Y_{Suma}$ [kN] | $Z_{Suma}$ [kN] |
|---|---|---|---|
| Suma de cargas HC FNormal | 84,82 | 37,70 | 0 |

Reacciones para FNormal, Suma FX: -84,8, Suma FY: -37,7, Suma FZ: 0,0
En los nodos [kN]/[kNm], Suma FX: -84,8, Suma FY: -37,7, Suma FZ: 0,0




**REACCIONES en nodos**

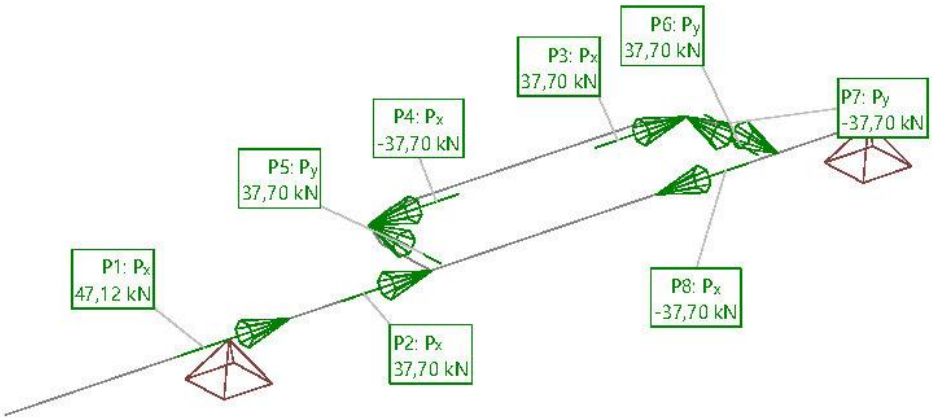
Cargas FNormal

| Nudo | Rot. | Fx [kN] | Fy [kN] | Fz [kN] | Mx [kNm] | My [kNm] | Mz [kNm] |
|---|---|---|---|---|---|---|---|
| K_1 | - | -74,4 | -25,7 | 0,0 | | | |
| K_2 | - | -10,4 | -12,0 | -0,0 | | | |
| Suma (global) | | -84,8 | -37,7 | -0,0 | | | |

Nr.:

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Hipótesis de carga Bypass: Funcion. bypass




**Hipótesis de carga 'Bypass': Funcion. bypass**

**Cargas puntuales: Fuerzas y momentos**

| Nombre | Tipo | P [kN] | M [kNm] | $X_{Suma}$ [kN] | $Y_{Suma}$ [kN] | $Z_{Suma}$ [kN] |
|---|---|---|---|---|---|---|
| P1 | X Global Fuerza en barra | 47,12 | | 47,12 | 0 | 0 |
| P2 | X Global Fuerza en barra | 37,70 | | 37,70 | 0 | 0 |
| P3 | X Global Fuerza en barra | 37,70 | | 37,70 | 0 | 0 |
| P4 | X Global Fuerza en barra | -37,70 | | -37,70 | 0 | 0 |
| P5 | Y Global Fuerza en barra | 37,70 | | 0 | 37,70 | 0 |
| P6 | Y Global Fuerza en barra | 37,70 | | 0 | 37,70 | 0 |
| P7 | Y Global Fuerza en barra | -37,70 | | 0 | -37,70 | 0 |
| P8 | X Global Fuerza en barra | -37,70 | | -37,70 | 0 | 0 |

**Suma de cargas**

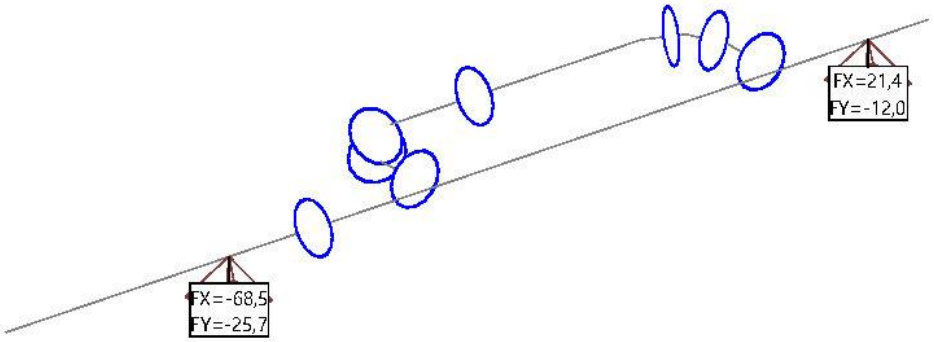
| | $X_{Suma}$ [kN] | $Y_{Suma}$ [kN] | $Z_{Suma}$ [kN] |
|---|---|---|---|
| Suma de cargas HC Bypass | 47,12 | 37,70 | 0 |

Nr.:

M:\PROES\Proyectos\2023\M23006 EMISARIO TIAS LANZAROTE\230027 IAS\01 Pozo hinca\01 Cálculos\Soportes tuberías 01.S9P

| Tías | Página 4 |
|---|---|
| Soportes tuberías 01 | 08.08.24, 17:29 |
| PROES S.A., 28020 Madrid . | Statik-9 - Rel. 241 (0) |

Reacciones para Bypass, Suma FX: -47,1, Suma FY: -37,7, Suma FZ: 0,0
En los nodos [kN]/[kNm], Suma FX: -47,1, Suma FY: -37,7, Suma FZ: 0,0




**REACCIONES en nodos**

Cargas Bypass

| Nudo | Rot. | Fx [kN] | Fy [kN] | Fz [kN] | Mx [kNm] | My [kNm] | Mz [kNm] |
|---|---|---|---|---|---|---|---|
| K_1 | - | -68,5 | -25,7 | 0,0 | | | |
| K_2 | - | 21,4 | -12,0 | -0,0 | | | |
| Suma (global) | | -47,1 | -37,7 | -0,0 | | | |

| | Nr.: |
|---|---|

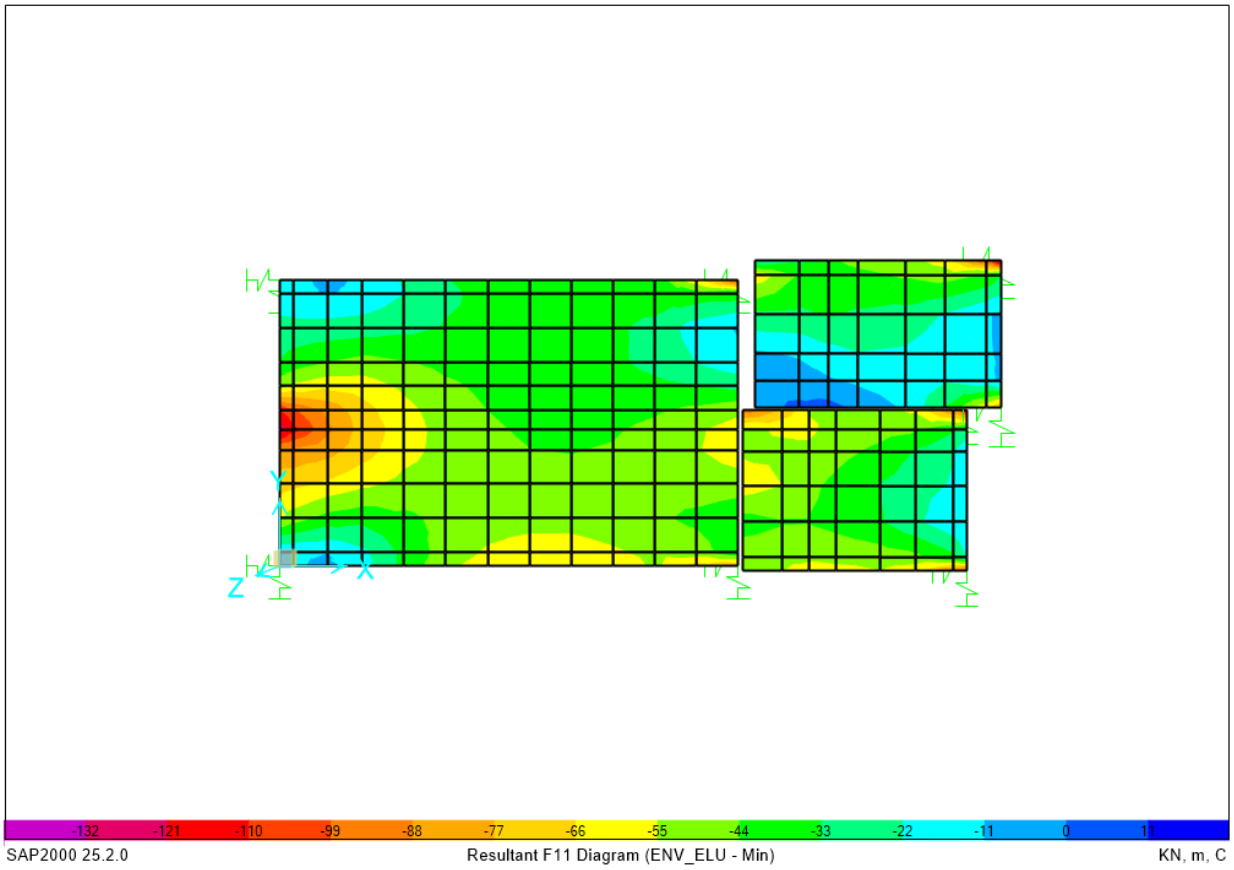
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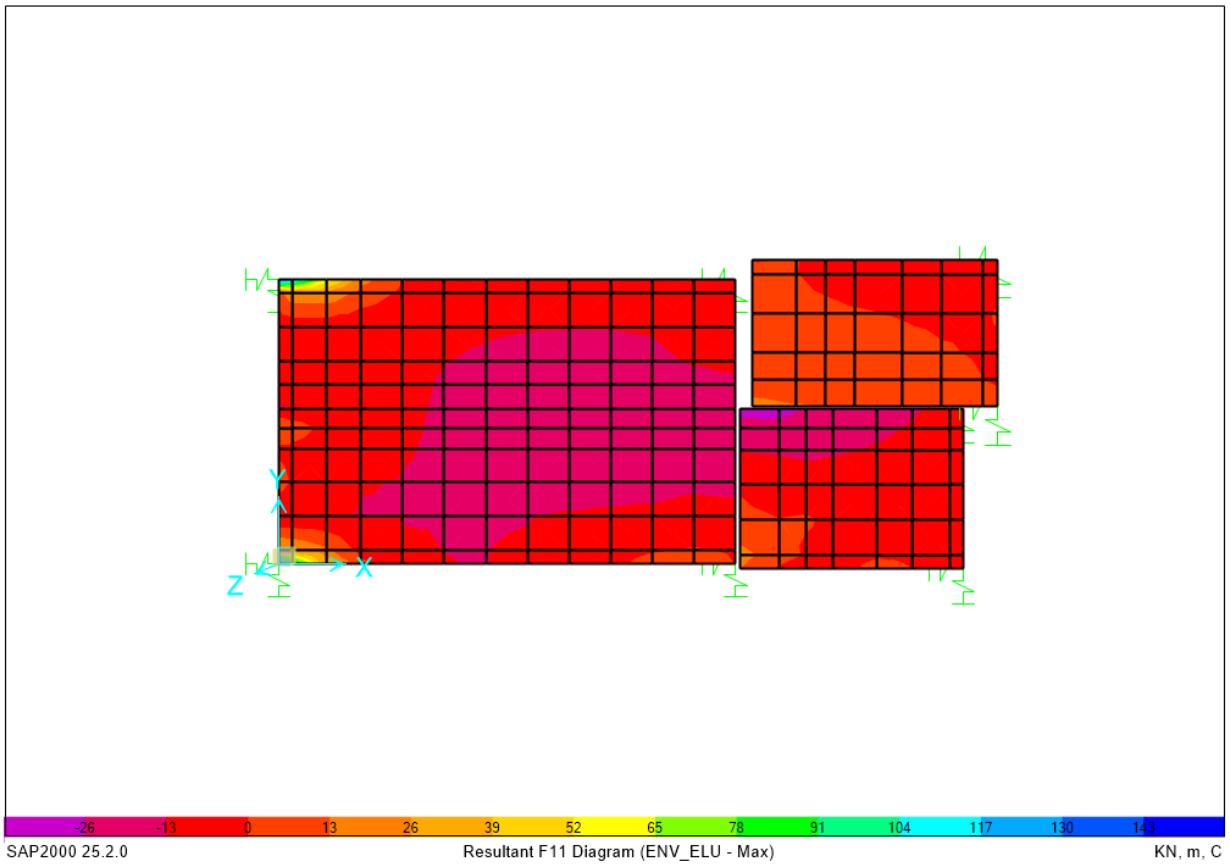
### 3.10.3 Resultados

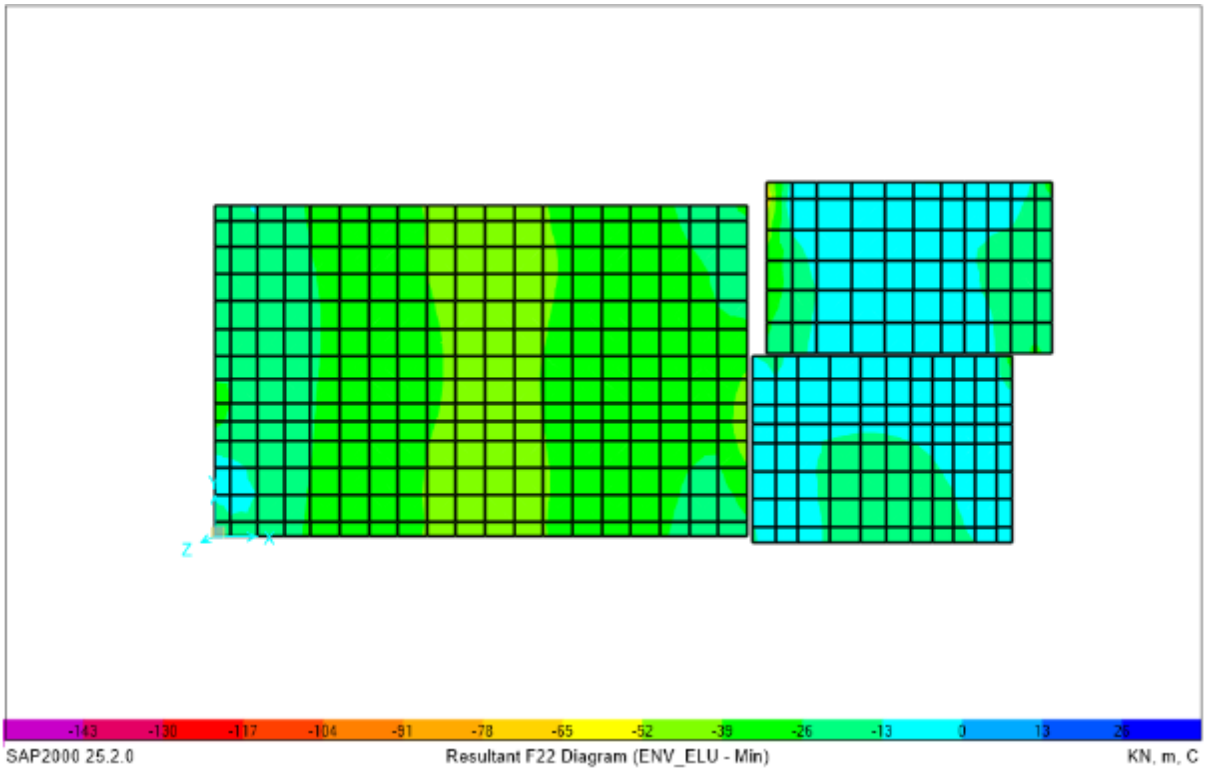
A continuación, se muestran los resultados del modelo para cada elemento estructural, diferenciando en losa inferior, muros, columnas y losa superior para todas las situaciones de diseño.

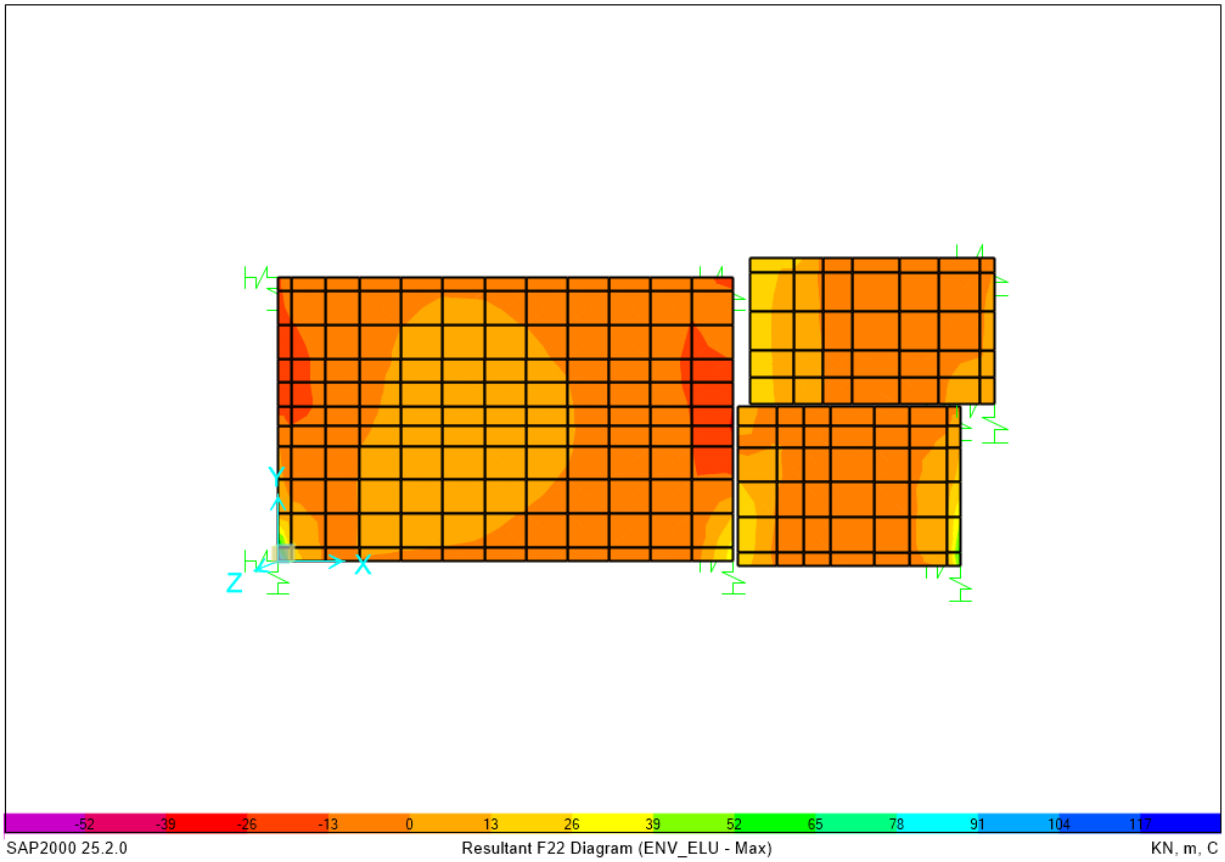
**Losa base inferior**

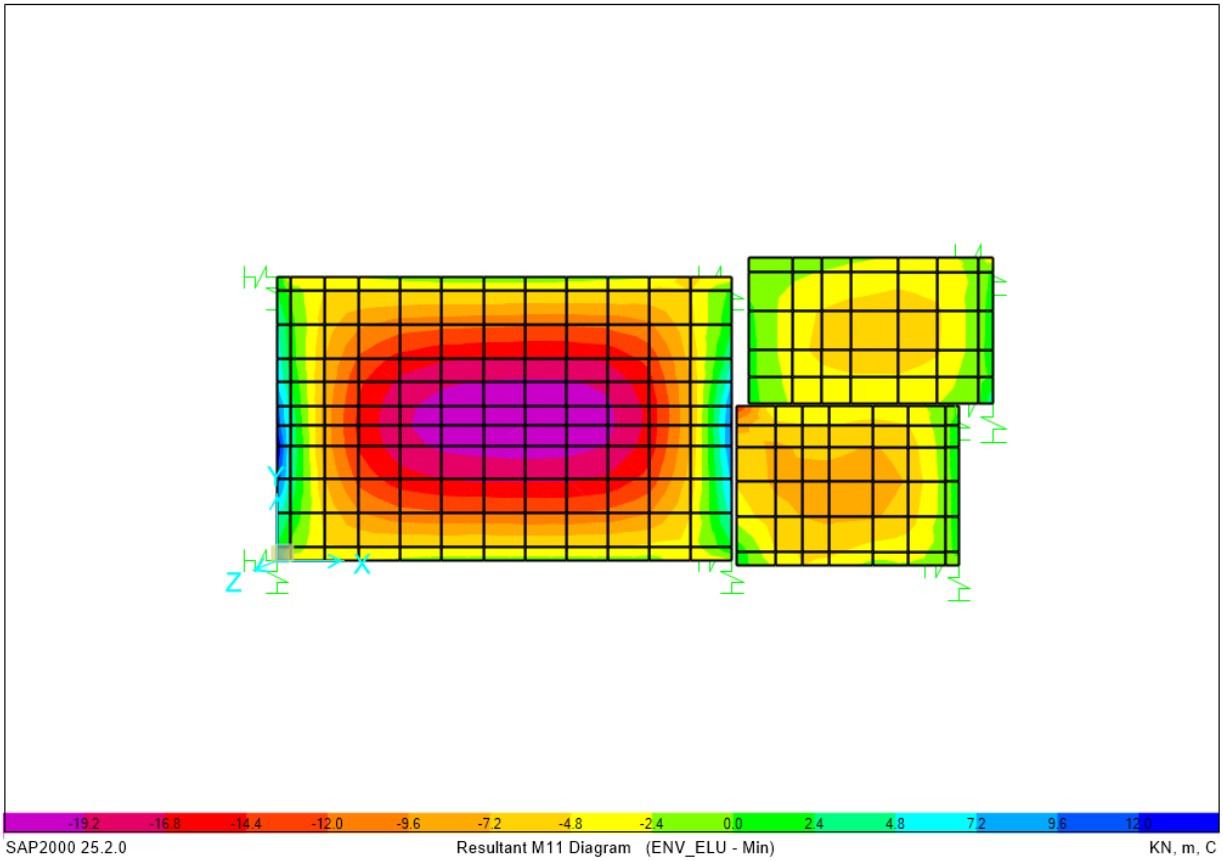
| LOSA BASE INFERIOR – ELU RESULTADOS | | | | | |
|---|---|---|---|---|---|
| | **$F_{11}$ (kN)** | **$M_{11}$ (kNm)** | **$F_{22}$ (kN)** | **$M_{22}$ (kNm)** | **$V_{max}$ (kN)** |
| **ELU (min)** | -118,33 | -30,35 | -127,15 | -30 | 1,22 |
| **ELU (max)** | 141,48 | 32,13 | 124,44 | 30,18 | 177,62 |

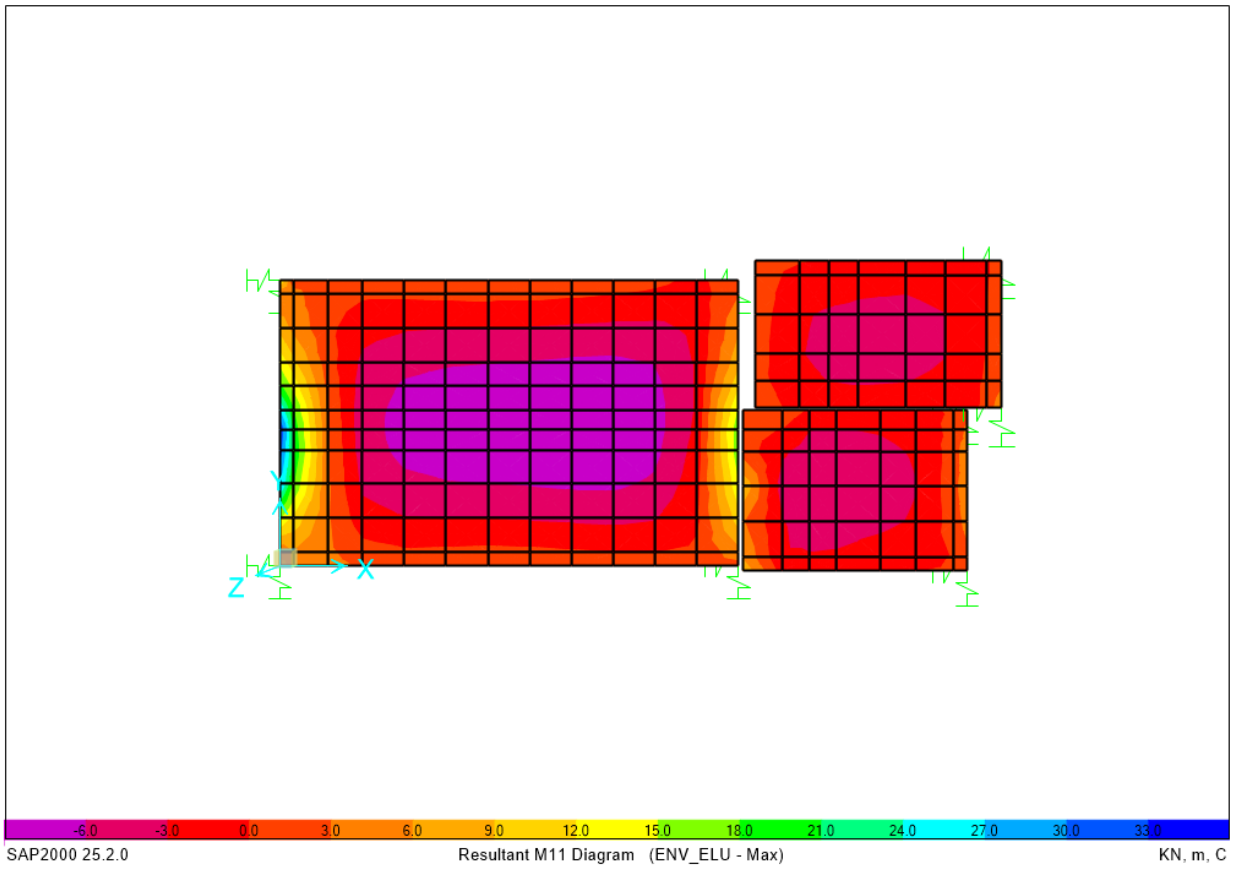


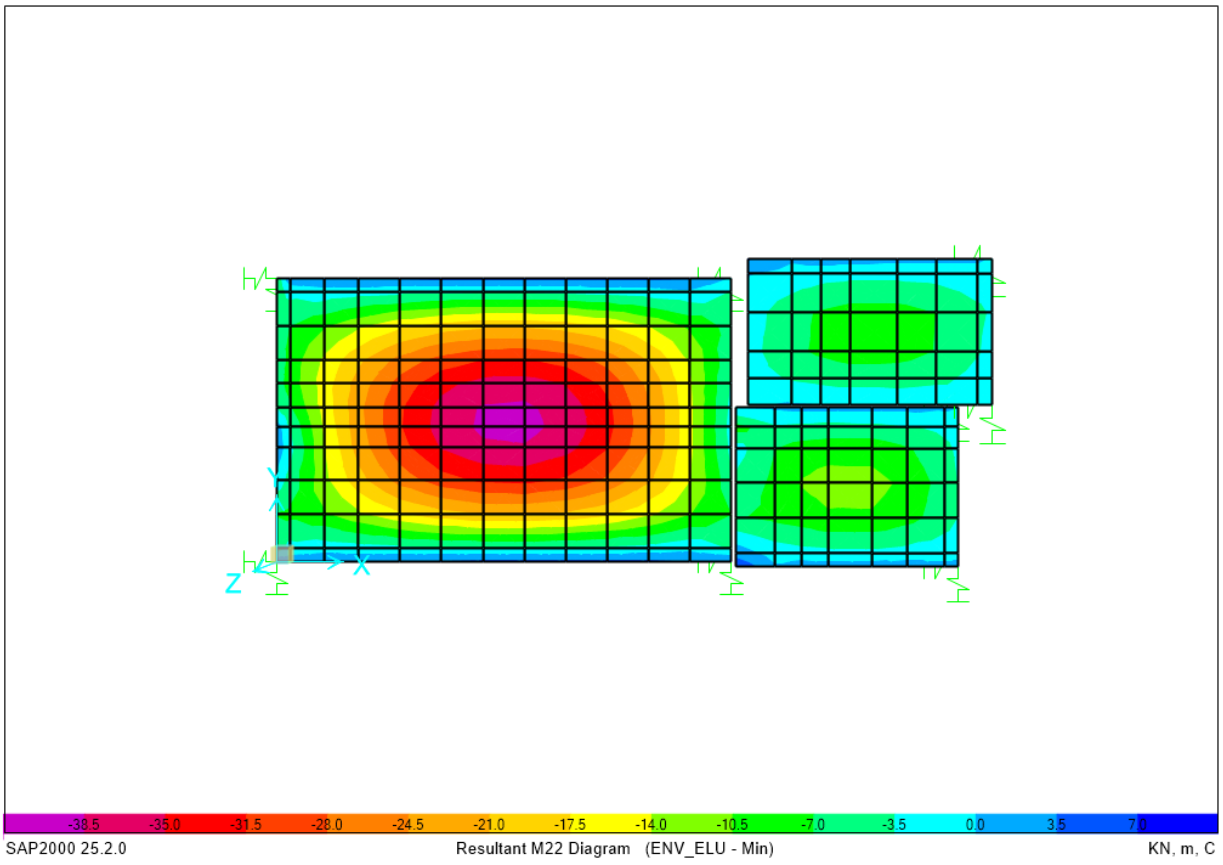

-26 -13 0 13 26 39 52 65 78 91 104 117 130 143
SAP2000 25.2.0
Resultant F11 Diagram (ENV_ELU - Max)
KN, m, C

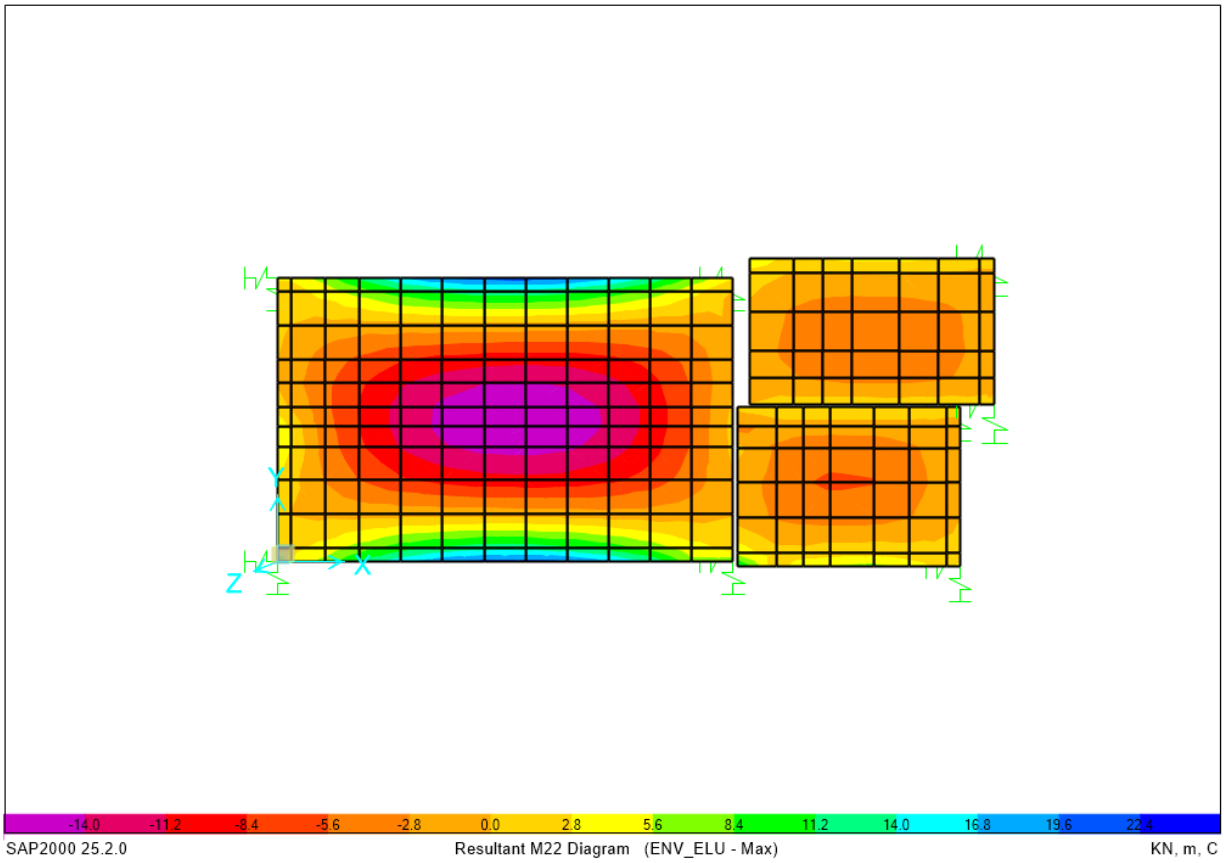

-143 -130 -117 -104 -91 -78 -65 -52 -39 -26 -13 0 13 26
SAP2000 25.2.0
Resultant F22 Diagram (ENV_ELU - Min)
KN, m, C

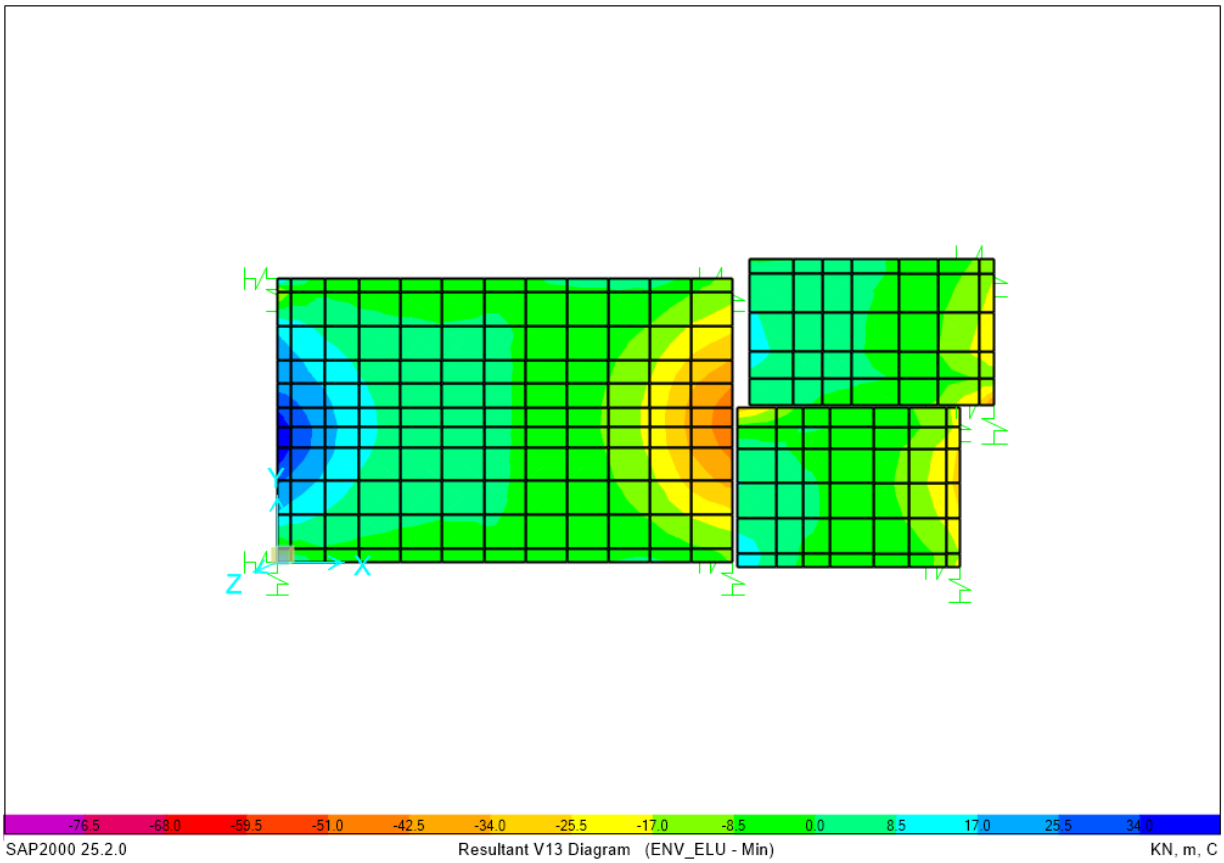

-52
-39
-26
-13
0
13
26
39
52
65
78
91
104
117
SAP2000 25.2.0
Resultant F22 Diagram (ENV_ELU - Max)
KN, m, C

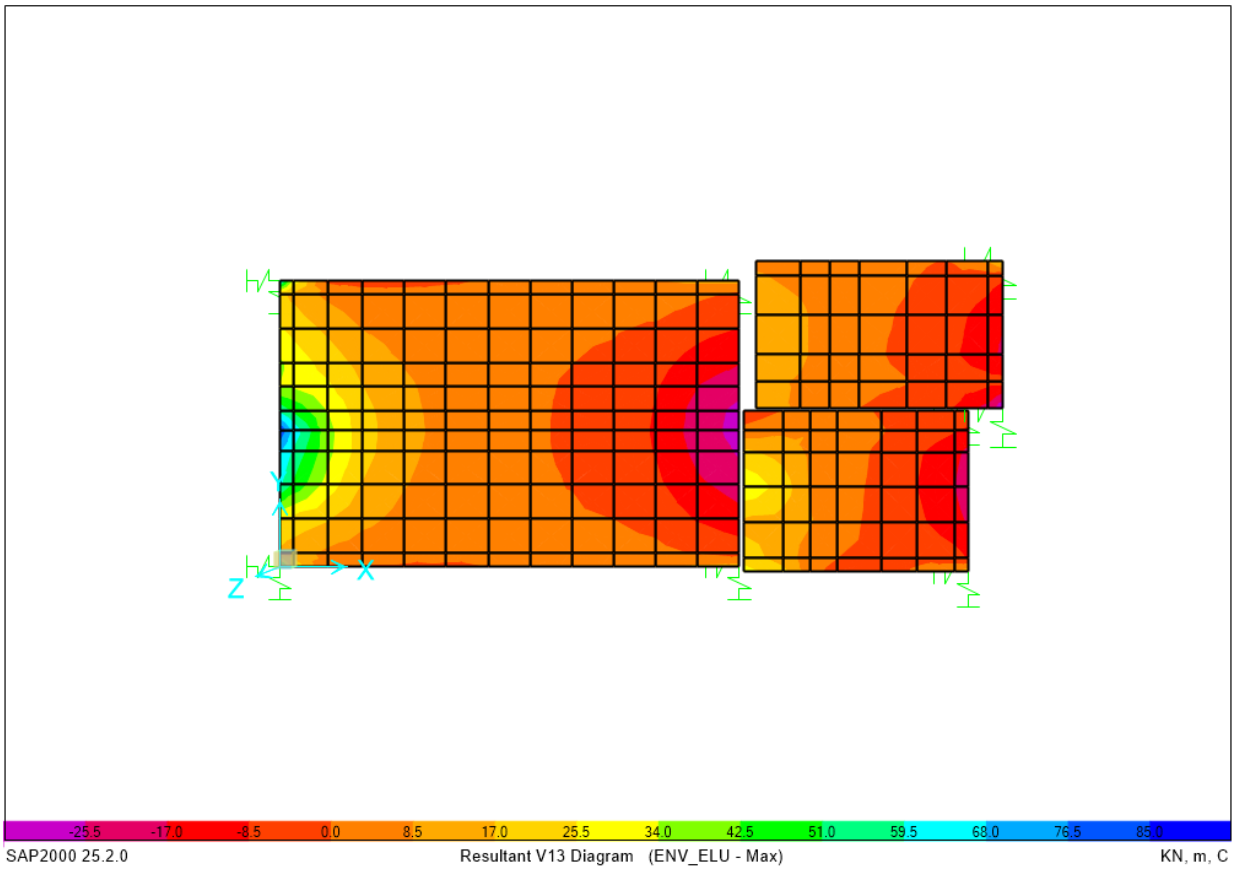

-19.2
-16.8
-14.4
-12.0
-9.6
-7.2
-4.8
-2.4
0.0
2.4
4.8
7.2
9.6
12.0
SAP2000 25.2.0
Resultant M11 Diagram (ENV_ELU - Min)
KN, m, C

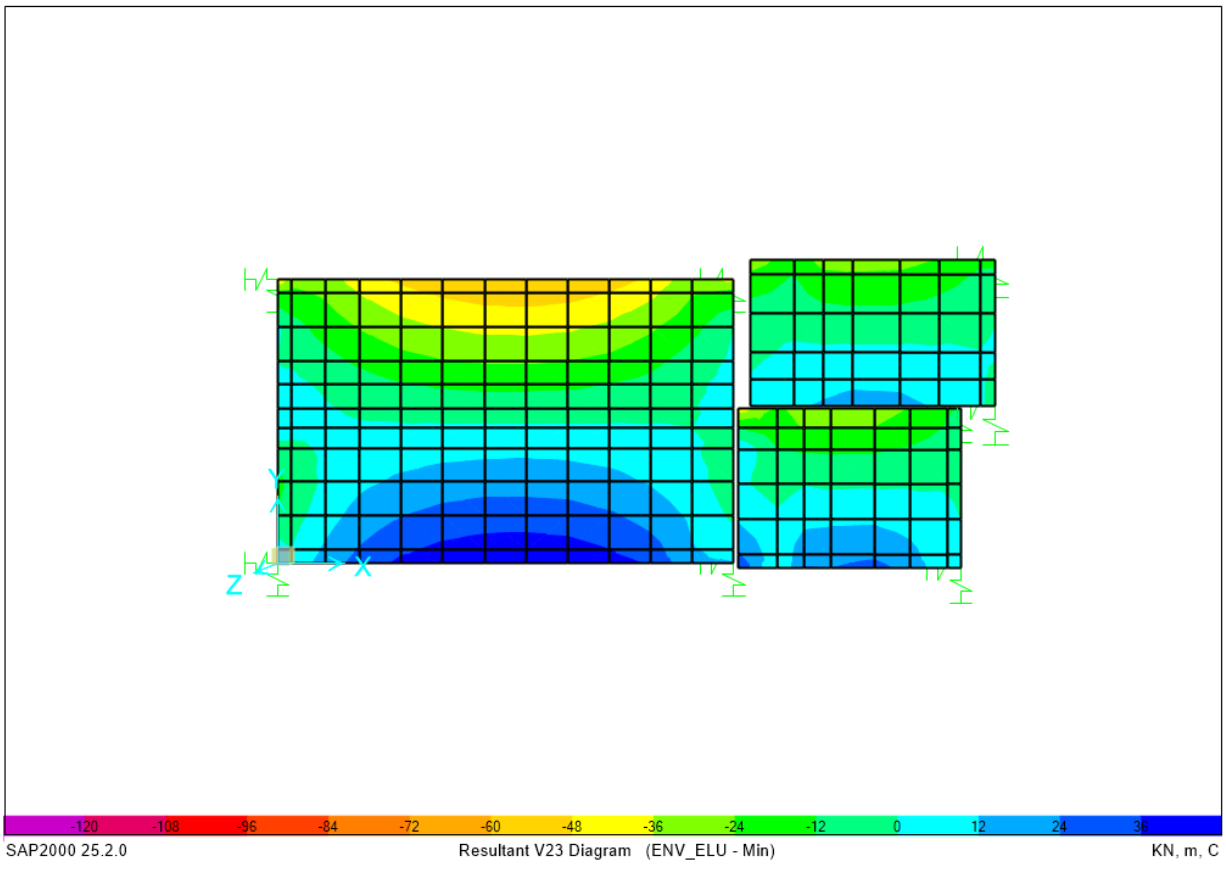

-6.0 -3.0 0.0 3.0 6.0 9.0 12.0 15.0 18.0 21.0 24.0 27.0 30.0 33.0
SAP2000 25.2.0
Resultant M11 Diagram (ENV_ELU - Max)
KN, m, C

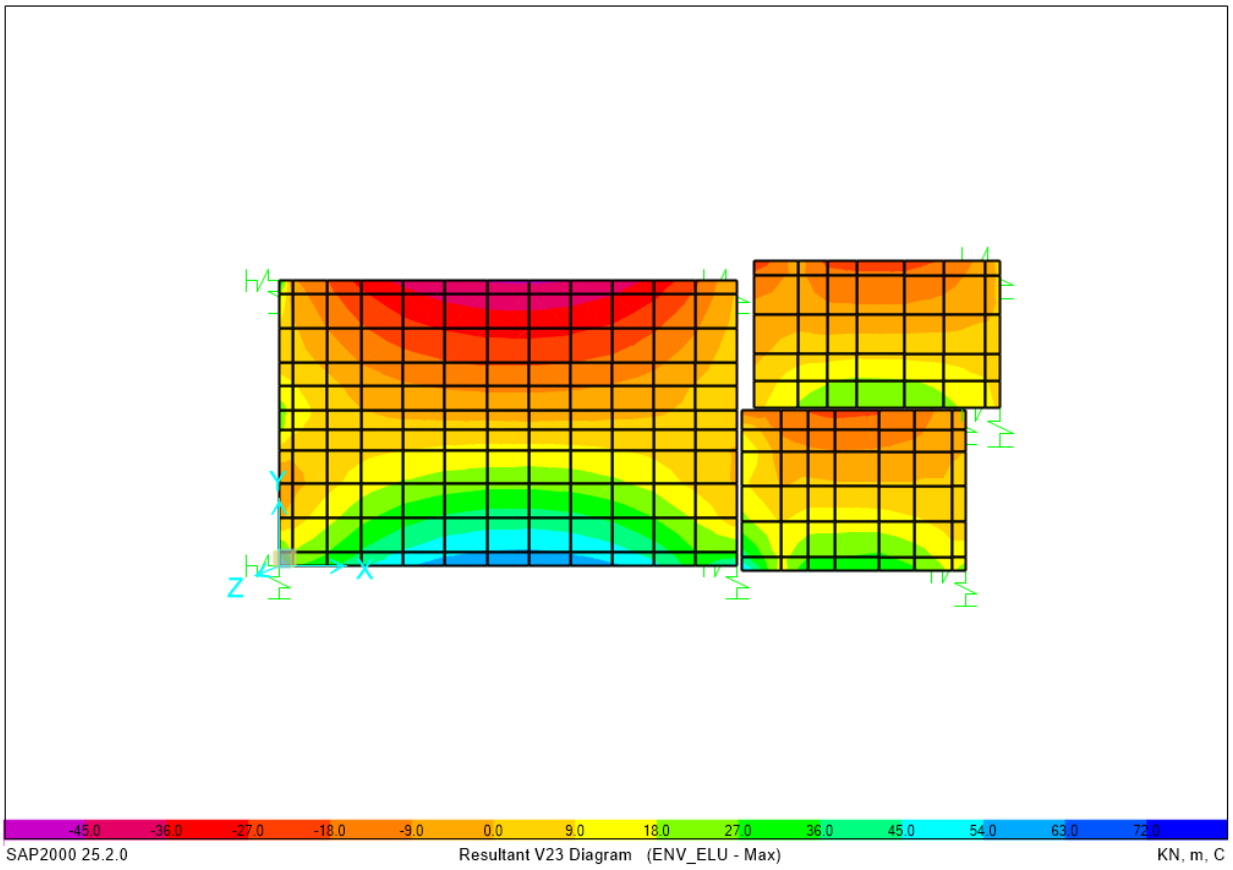

-38.5 -35.0 -31.5 -28.0 -24.5 -21.0 -17.5 -14.0 -10.5 -7.0 -3.5 0.0 3.5 7.0
SAP2000 25.2.0
Resultant M22 Diagram (ENV_ELU - Min)
KN, m, C


-14.0 -11.2 -8.4 -5.6 -2.8 0.0 2.8 5.6 8.4 11.2 14.0 16.8 19.6 22.4
SAP2000 25.2.0
Resultant M22 Diagram (ENV_ELU - Max)
KN, m, C


-76.5 -68.0 -59.5 -51.0 -42.5 -34.0 -25.5 -17.0 -8.5 0.0 8.5 17.0 25.5 34.0
SAP2000 25.2.0
Resultant V13 Diagram (ENV_ELU - Min)
KN, m, C

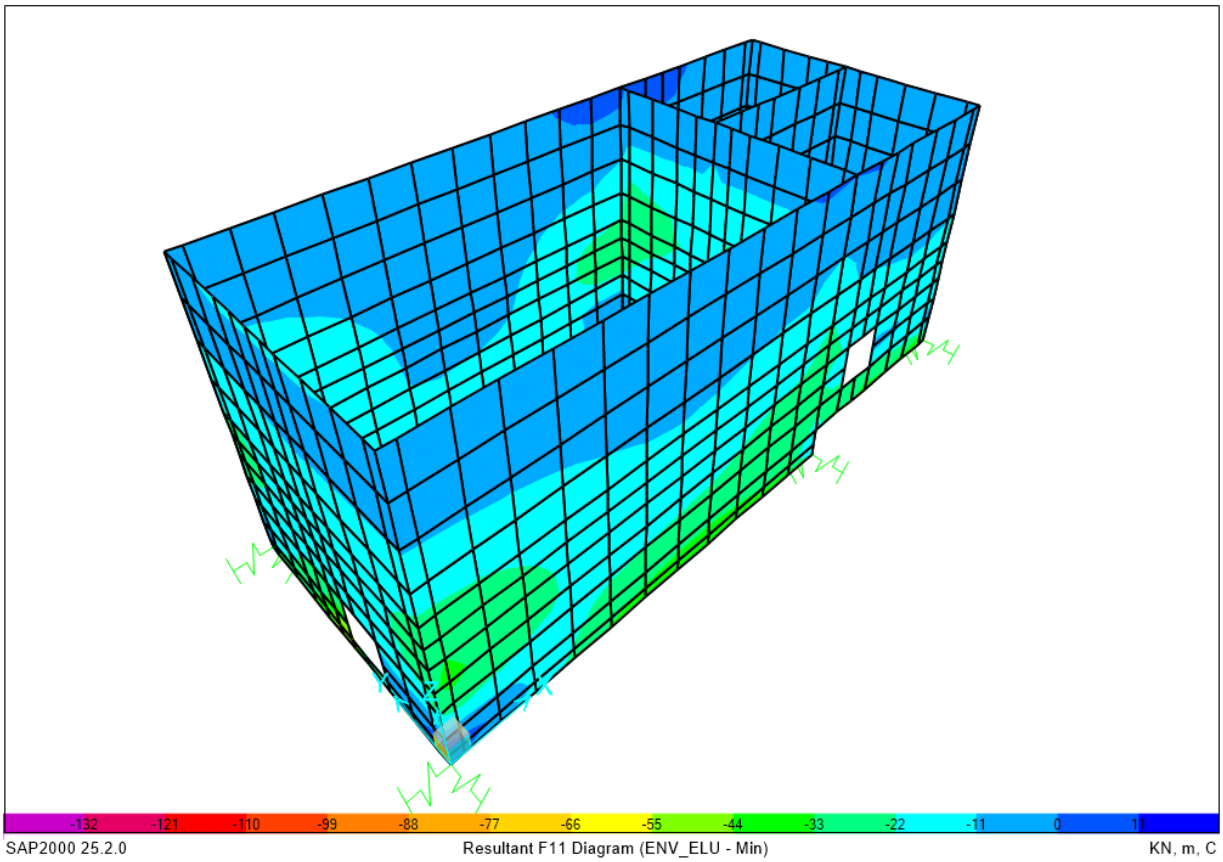

-25.5 -17.0 -8.5 0.0 8.5 17.0 25.5 34.0 42.5 51.0 59.5 68.0 76.5 85.0
SAP2000 25.2.0
Resultant V13 Diagram (ENV_ELU - Max)
KN, m, C

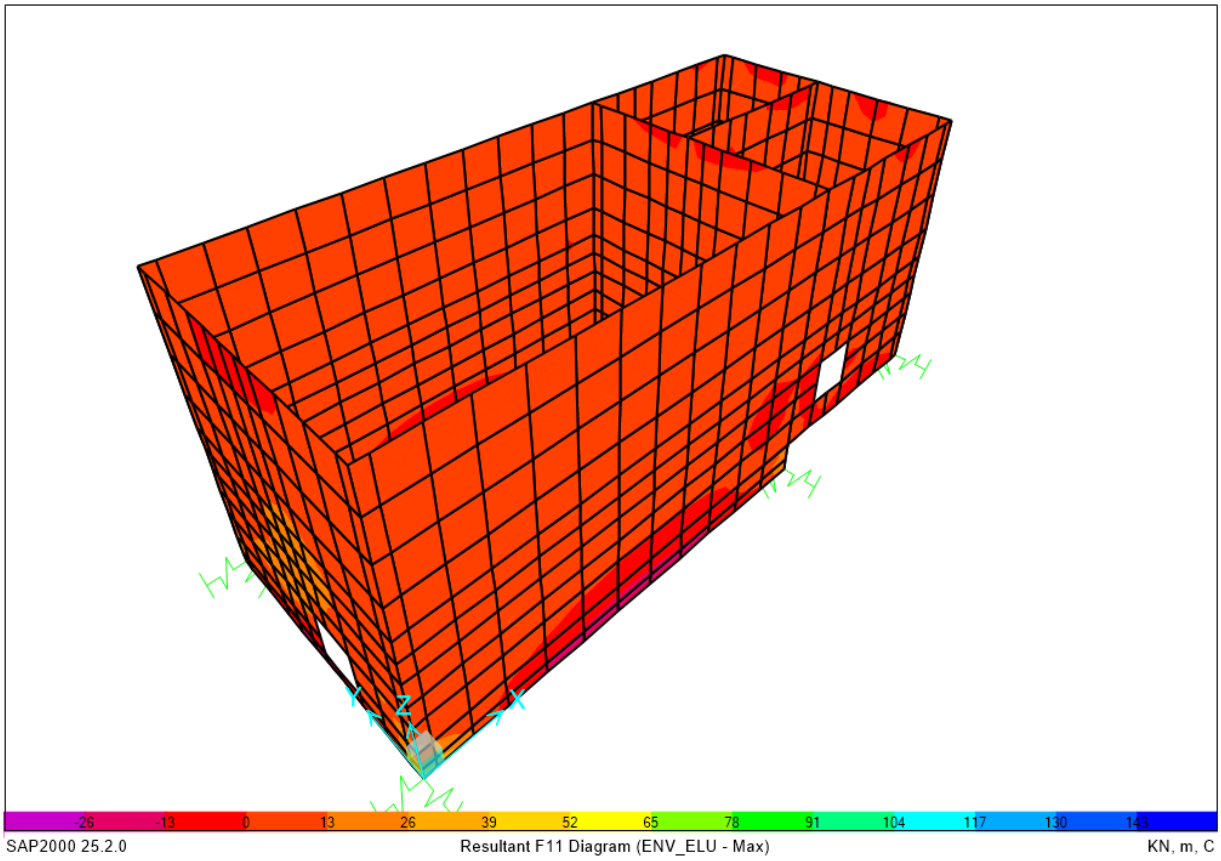

-120 -108 -96 -84 -72 -60 -48 -36 -24 -12 0 12 24 36
SAP2000 25.2.0
Resultant V23 Diagram (ENV_ELU - Min)
KN, m, C

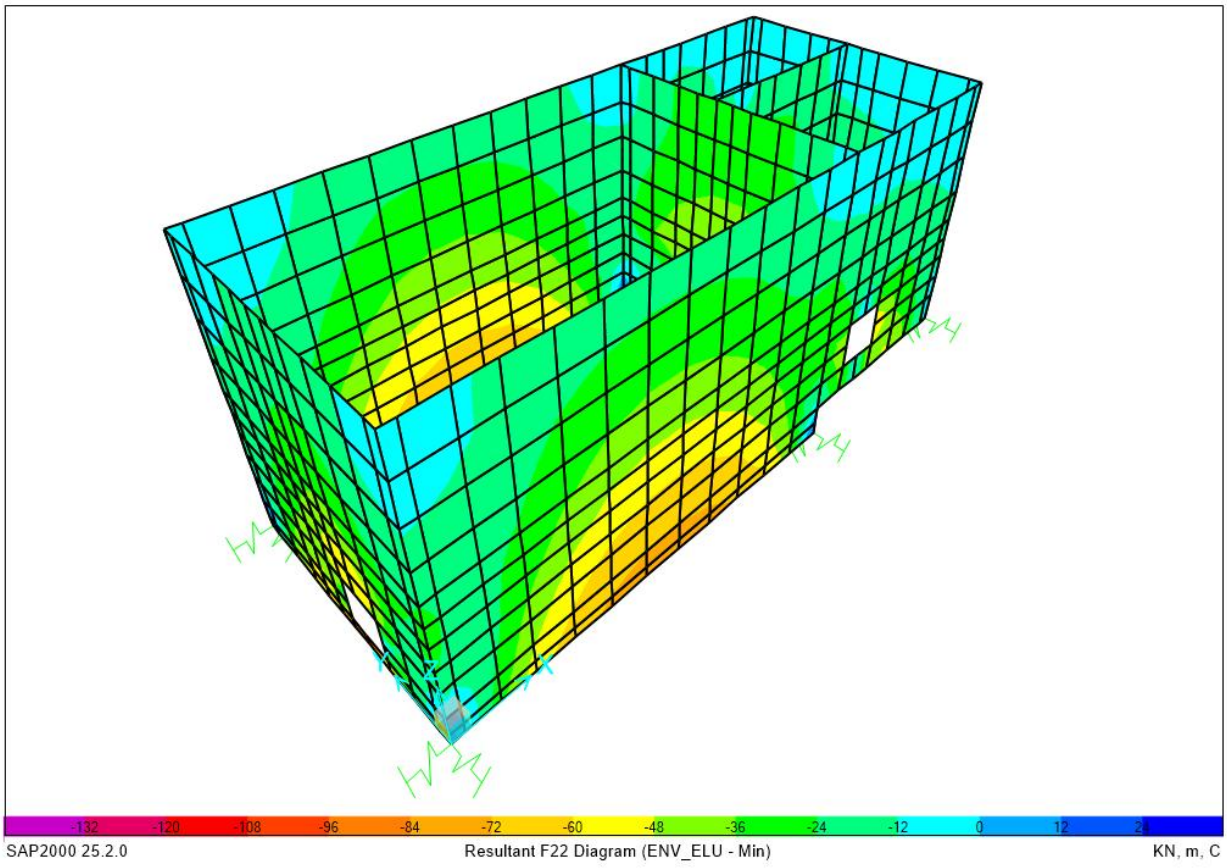


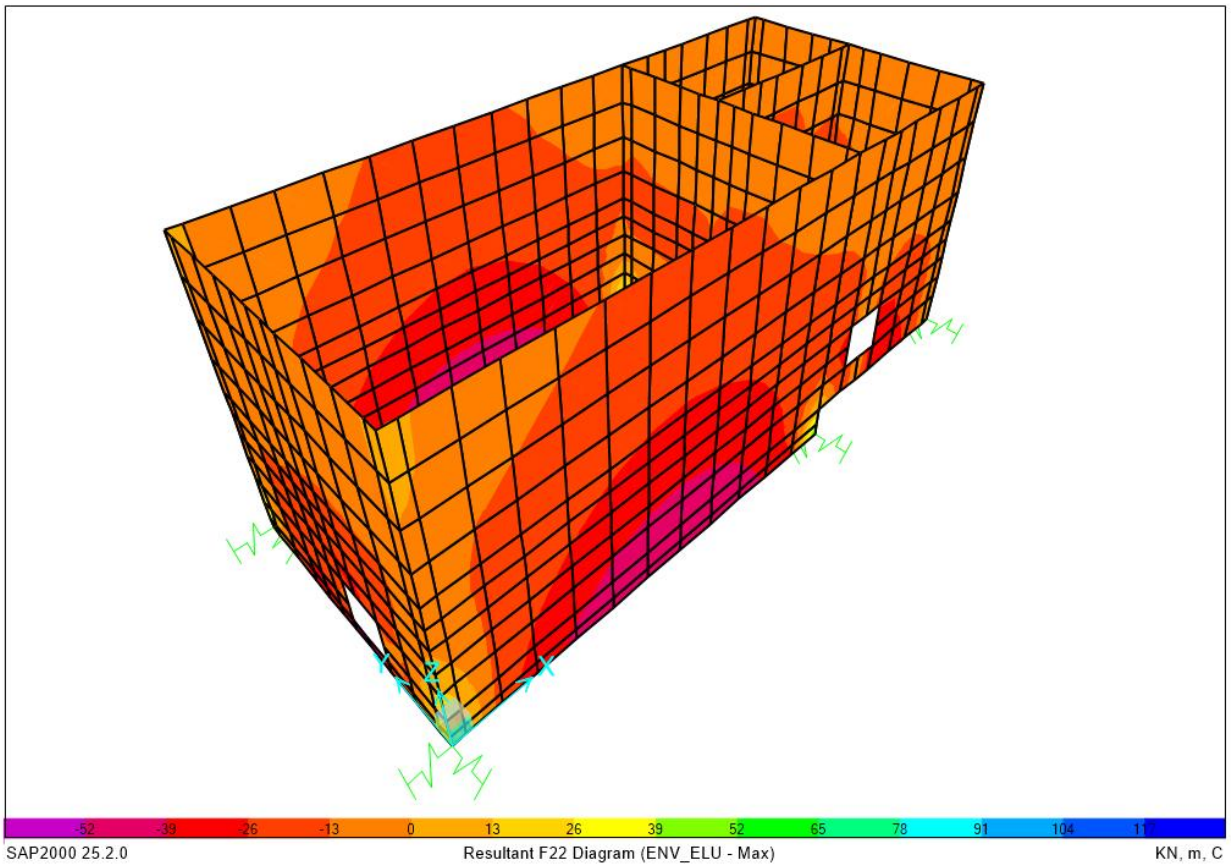

**Muros**

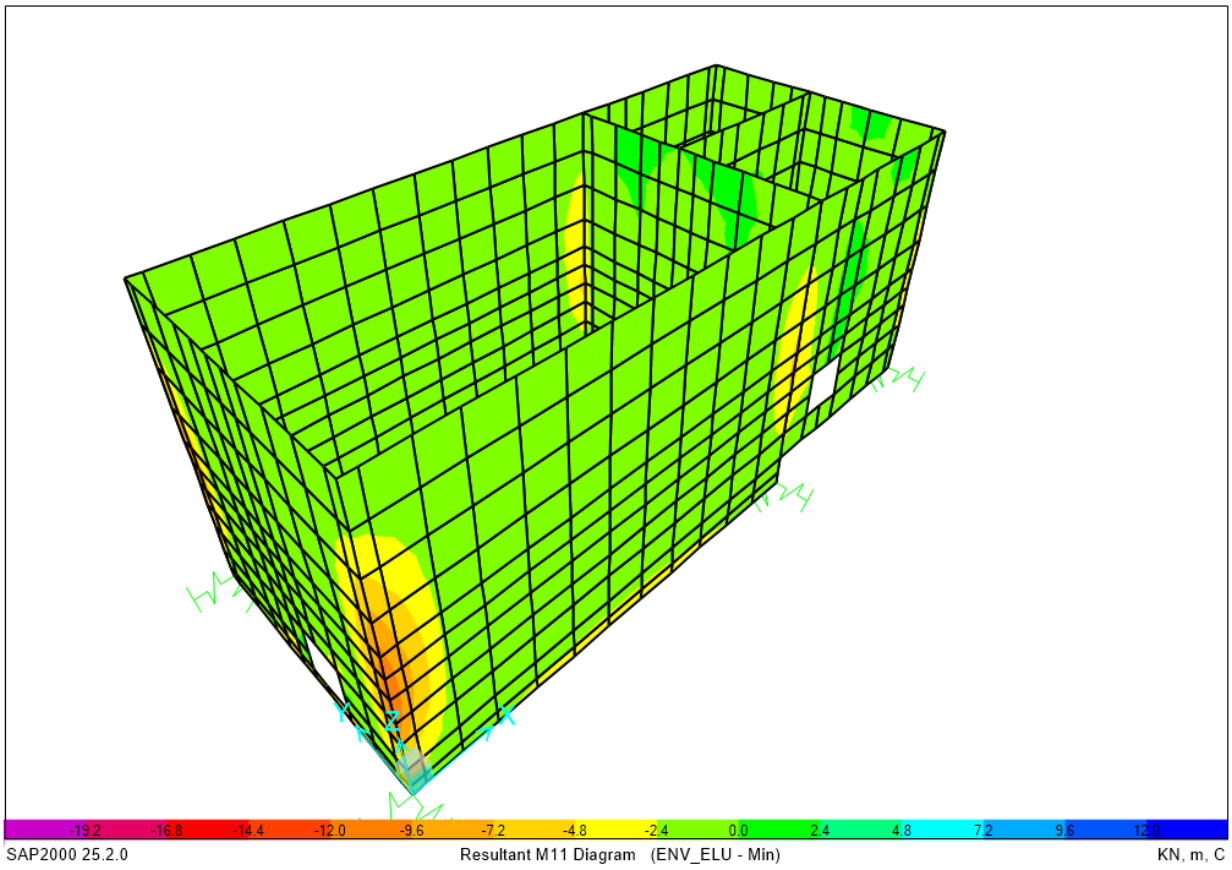
| MUROS – LRFD RESULTADOS | | | | | |
|---|---|---|---|---|---|
| | **$F_{11}$ (kN)** | **$M_{11}$ (kNm)** | **$F_{22}$ (kN)** | **$M_{22}$ (kNm)** | **Vmax (kN)** |
| **ELU (min)** | -78,97 | -12,18 | -107,24 | -32,73 | 0,01 |
| **ELU (max)** | 86,88 | 19,43 | 60,09 | 17,15 | 108 |

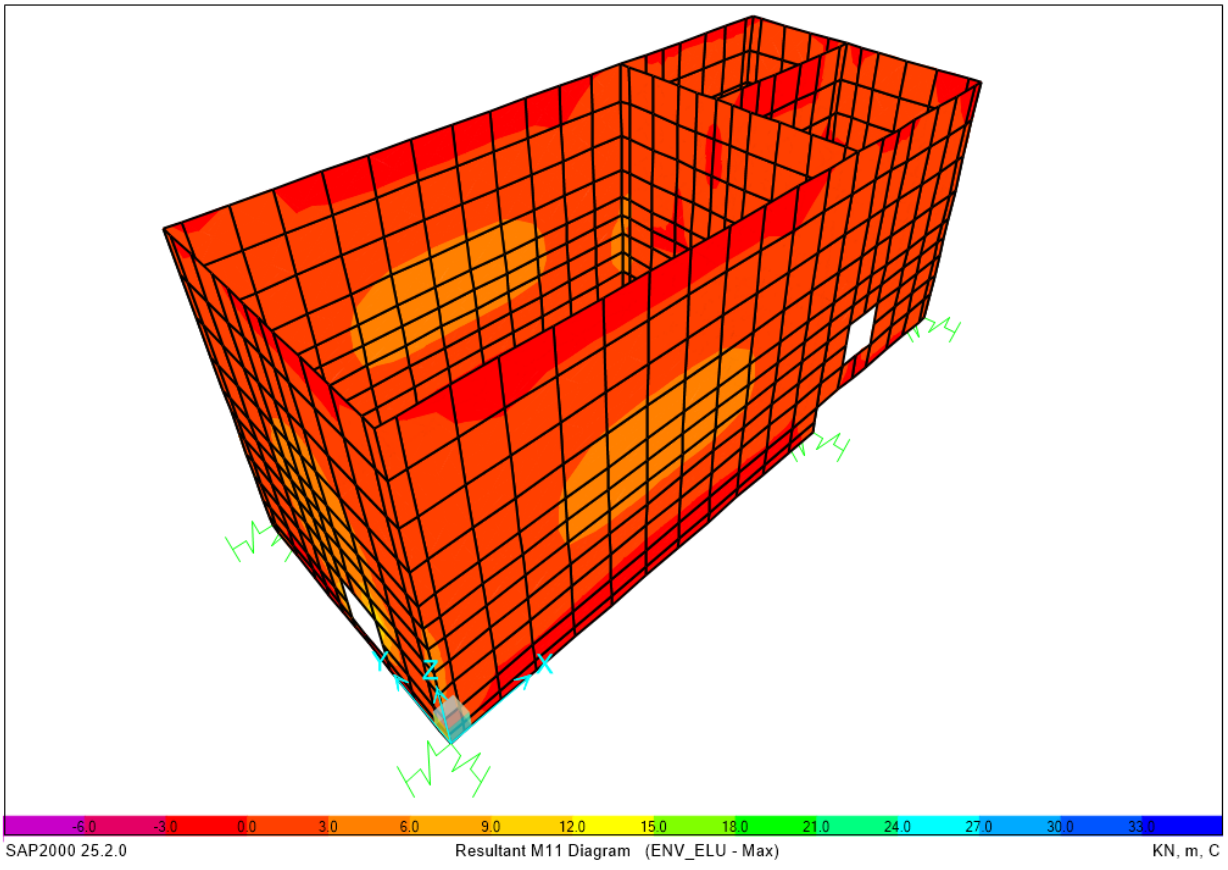

-132 -121 -110 -99 -88 -77 -66 -55 -44 -33 -22 -11 0 11
SAP2000 25.2.0
Resultant F11 Diagram (ENV_ELU - Min)
KN, m, C

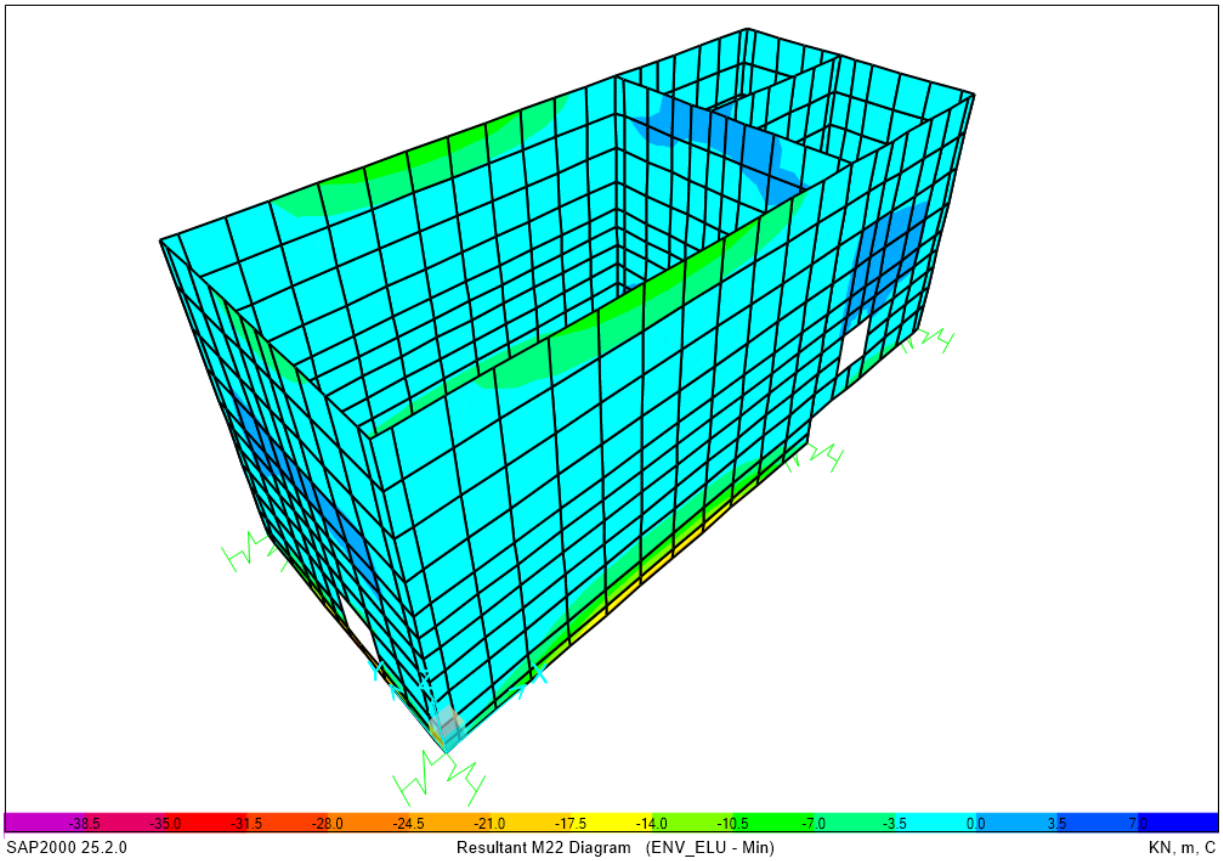

-26 -13 0 13 26 39 52 65 78 91 104 117 130 143
SAP2000 25.2.0
Resultant F11 Diagram (ENV_ELU - Max)
KN, m, C

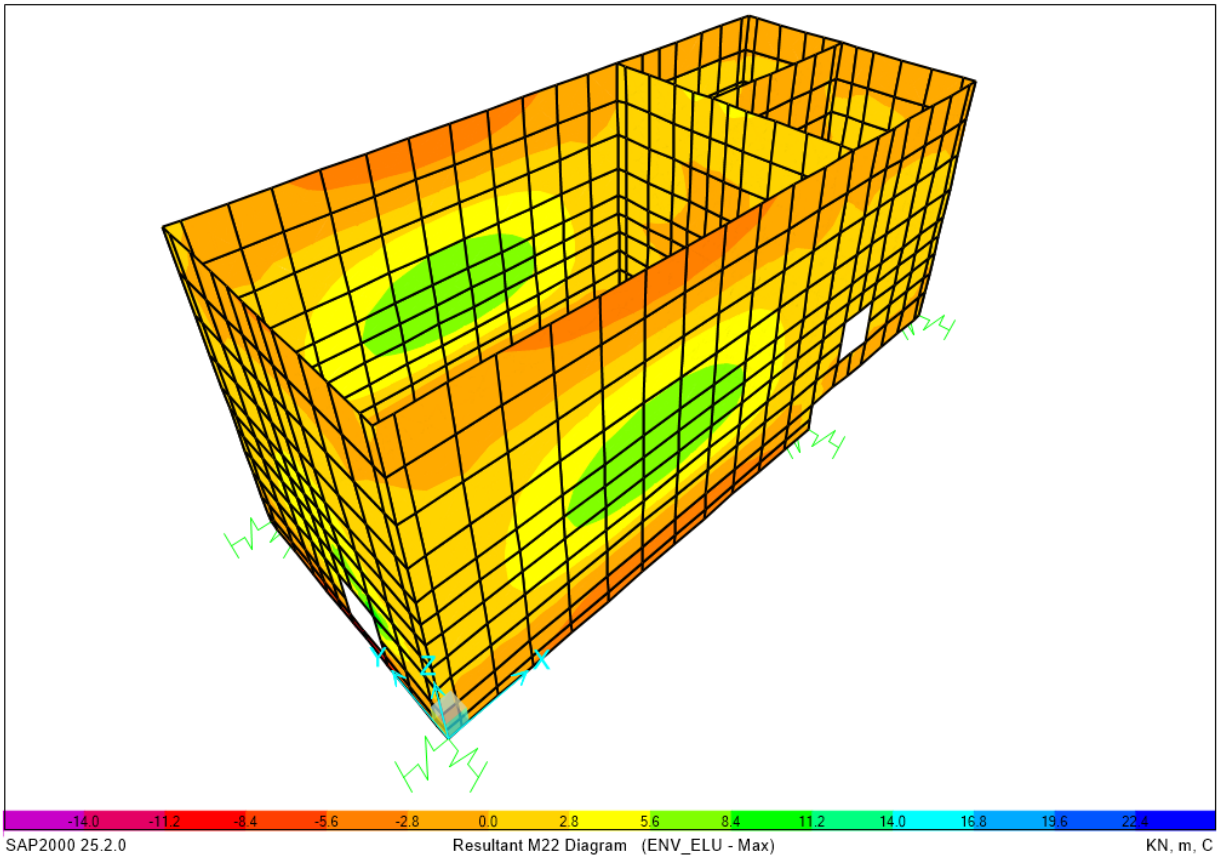

-132 -120 -108 -96 -84 -72 -60 -48 -36 -24 -12 0 12
SAP2000 25.2.0
Resultant F22 Diagram (ENV_ELU - Min)
KN, m, C

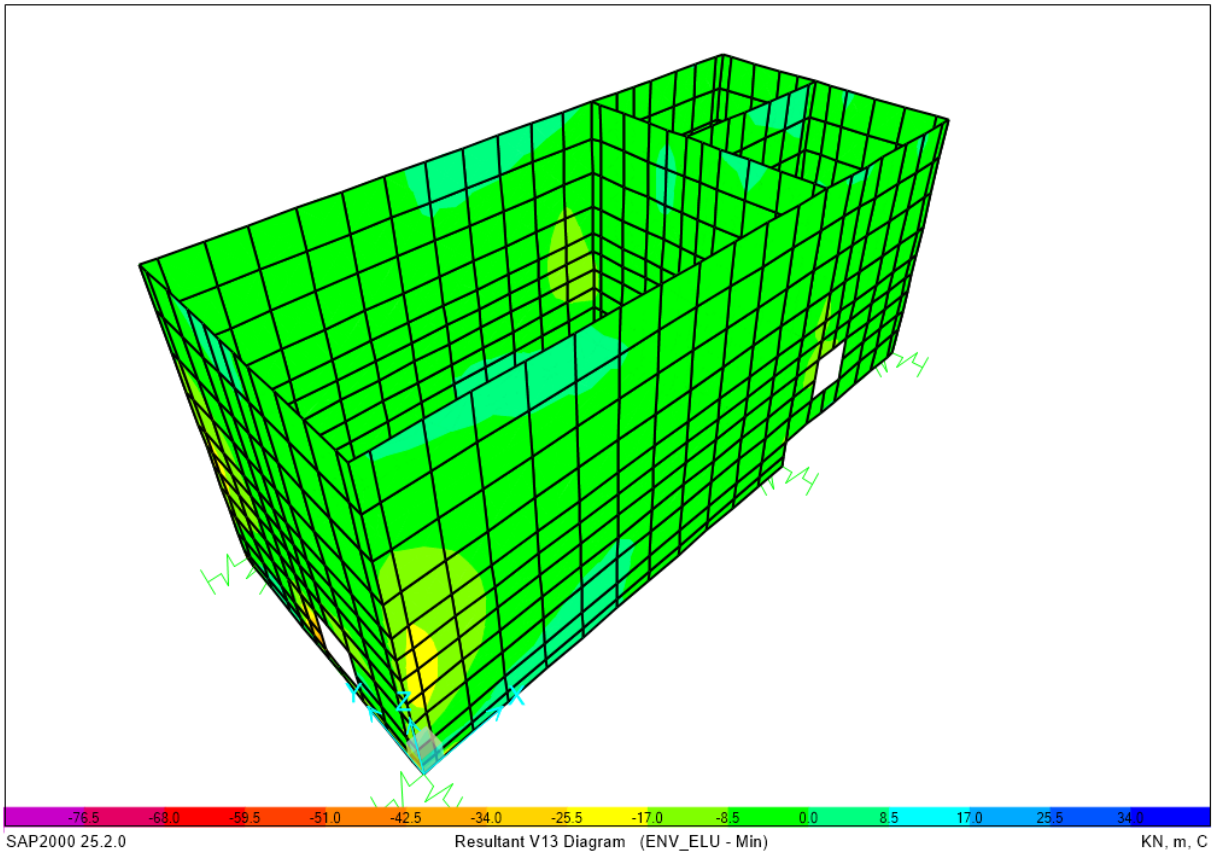

-52 -39 -26 -13 0 13 26 39 52 65 78 91 104
SAP2000 25.2.0
Resultant F22 Diagram (ENV_ELU - Max)
KN, m, C

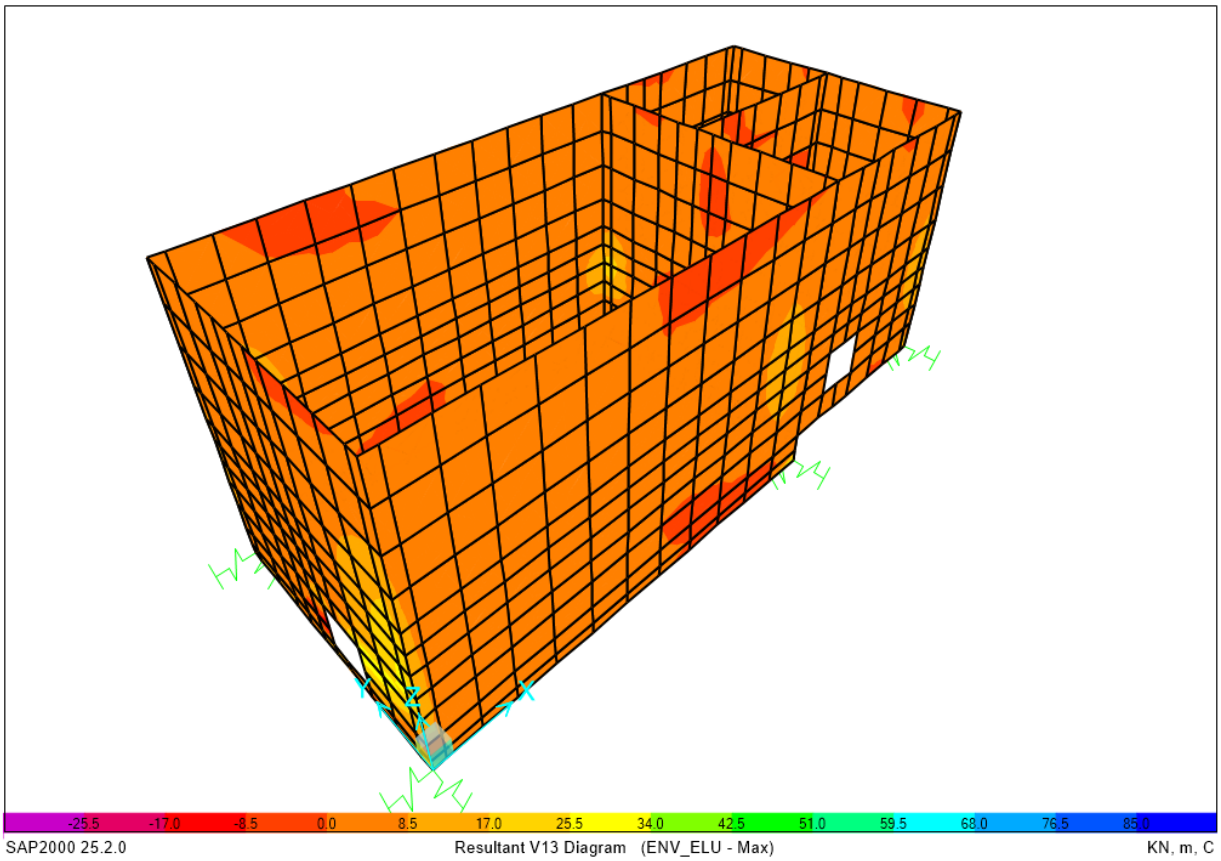

-19.2 -16.8 -14.4 -12.0 -9.6 -7.2 -4.8 -2.4 0.0 2.4 4.8 7.2 9.6 12.0
SAP2000 25.2.0
Resultant M11 Diagram (ENV_ELU - Min)
KN, m, C

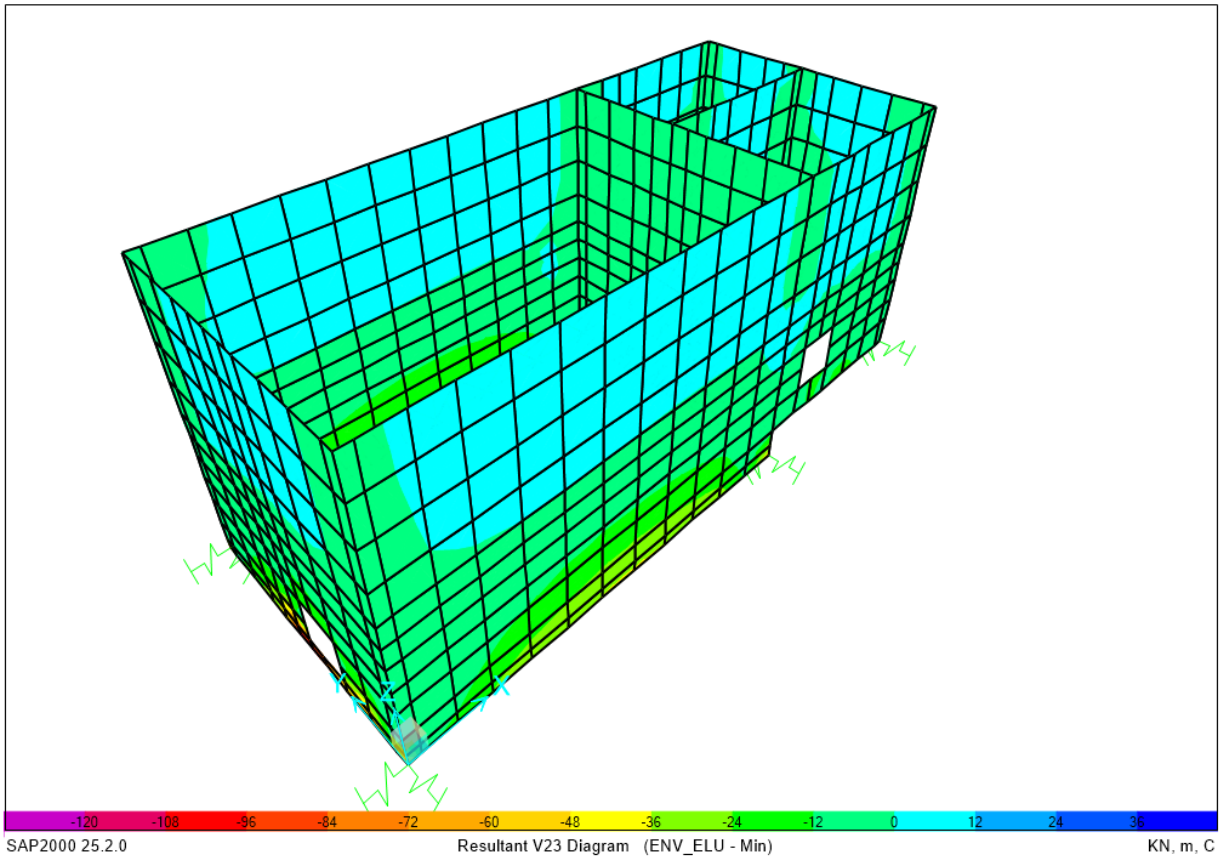

-6.0 -3.0 0.0 3.0 6.0 9.0 12.0 15.0 18.0 21.0 24.0 27.0 30.0 33.0
SAP2000 25.2.0
Resultant M11 Diagram (ENV_ELU - Max)
KN, m, C

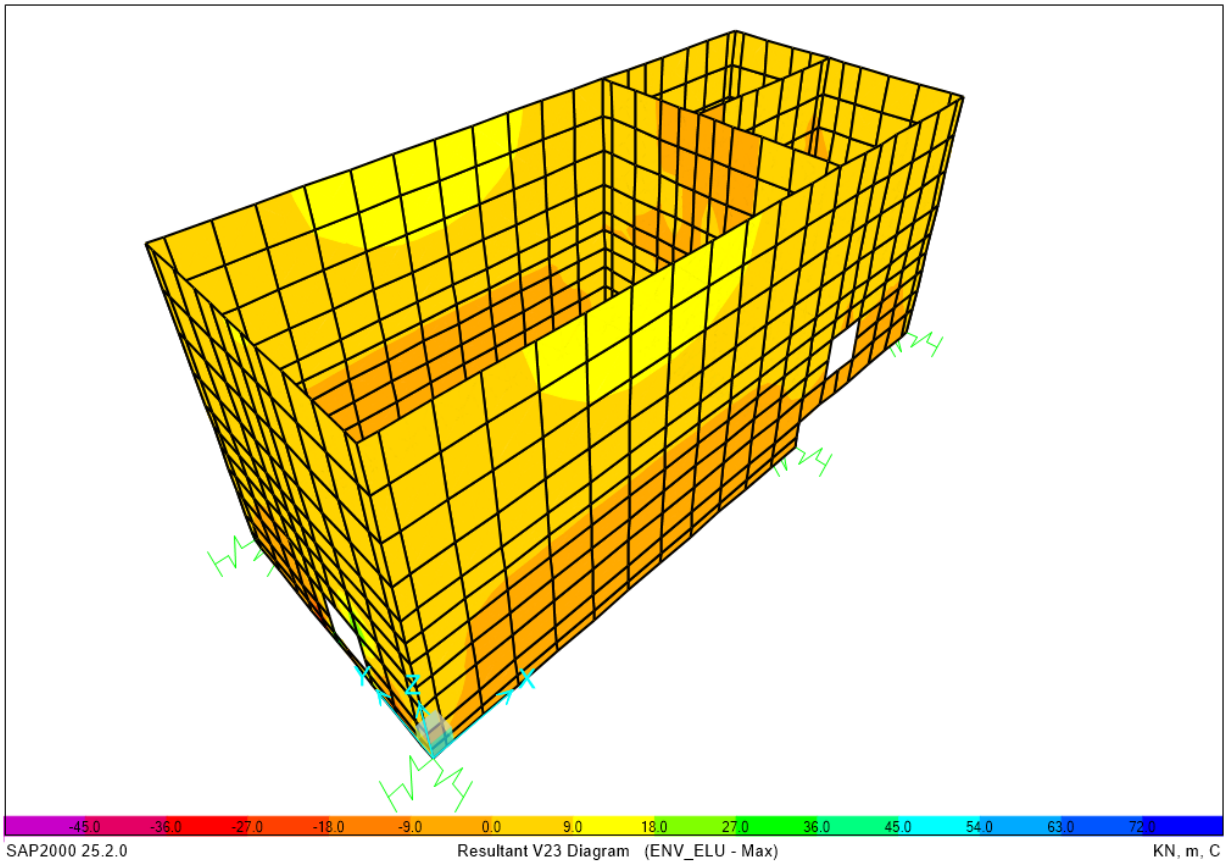

-38.5 -35.0 -31.5 -28.0 -24.5 -21.0 -17.5 -14.0 -10.5 -7.0 -3.5 0.0 3.5 7.0
SAP2000 25.2.0
Resultant M22 Diagram (ENV_ELU - Min)
KN, m, C


-14.0 -11.2 -8.4 -5.6 -2.8 0.0 2.8 5.6 8.4 11.2 14.0 16.8 19.6 22.4
SAP2000 25.2.0
Resultant M22 Diagram (ENV_ELU - Max)
KN, m, C


-76.5 -68.0 -59.5 -51.0 -42.5 -34.0 -25.5 -17.0 -8.5 0.0 8.5 17.0 25.5 34.0
SAP2000 25.2.0
Resultant V13 Diagram (ENV_ELU - Min)
KN, m, C

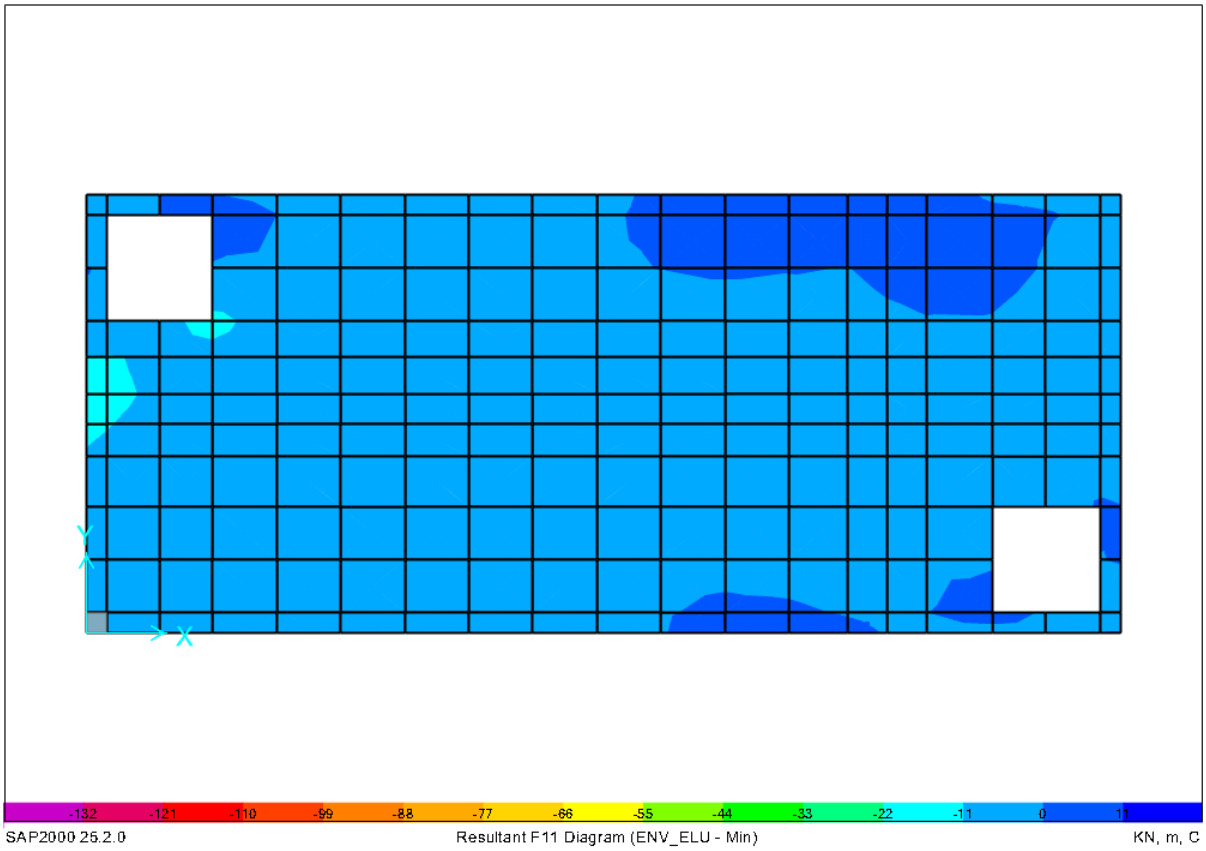

-25.5 -17.0 -8.5 0.0 8.5 17.0 25.5 34.0 42.5 51.0 59.5 68.0 76.5 85.0
SAP2000 25.2.0
Resultant V13 Diagram (ENV_ELU - Max)
KN, m, C

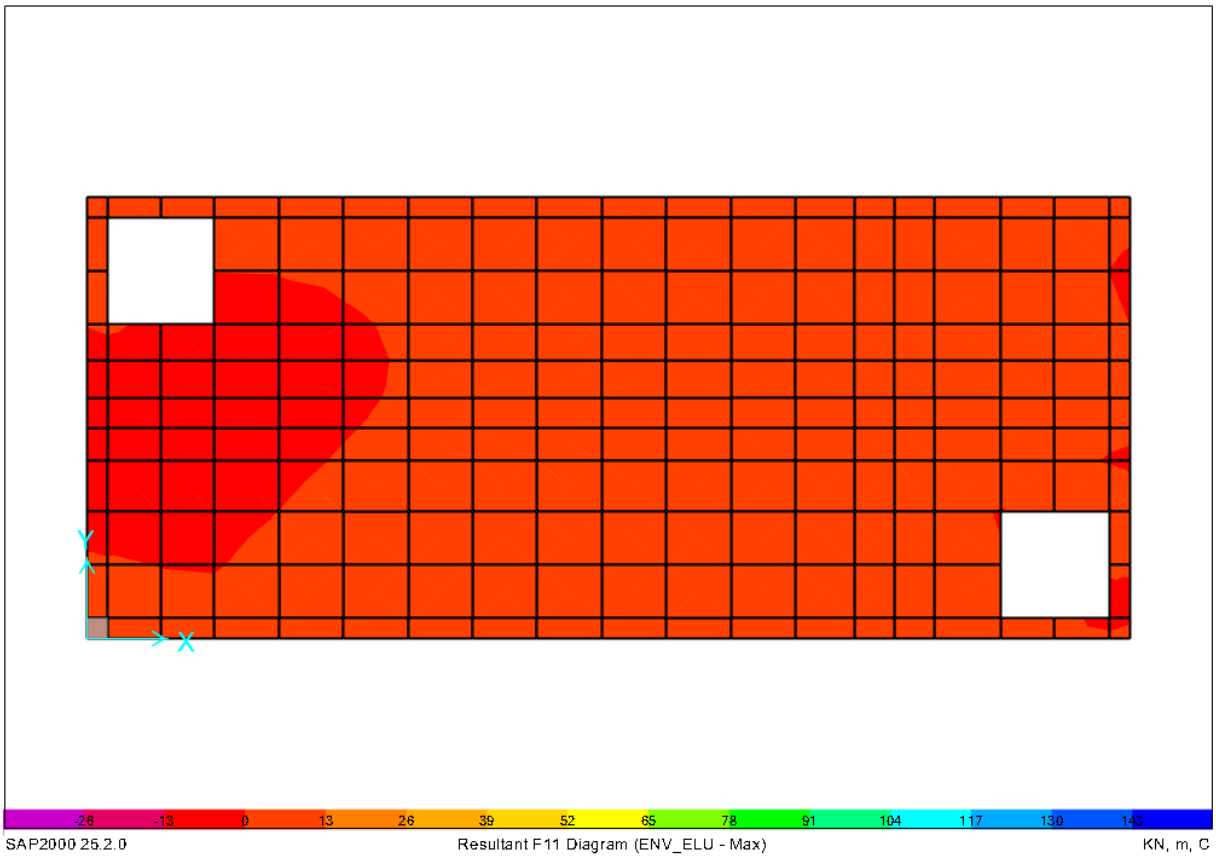

-120 -108 -96 -84 -72 -60 -48 -36 -24 -12 0 12 24 36
SAP2000 25.2.0
Resultant V23 Diagram (ENV_ELU - Min)
KN, m, C

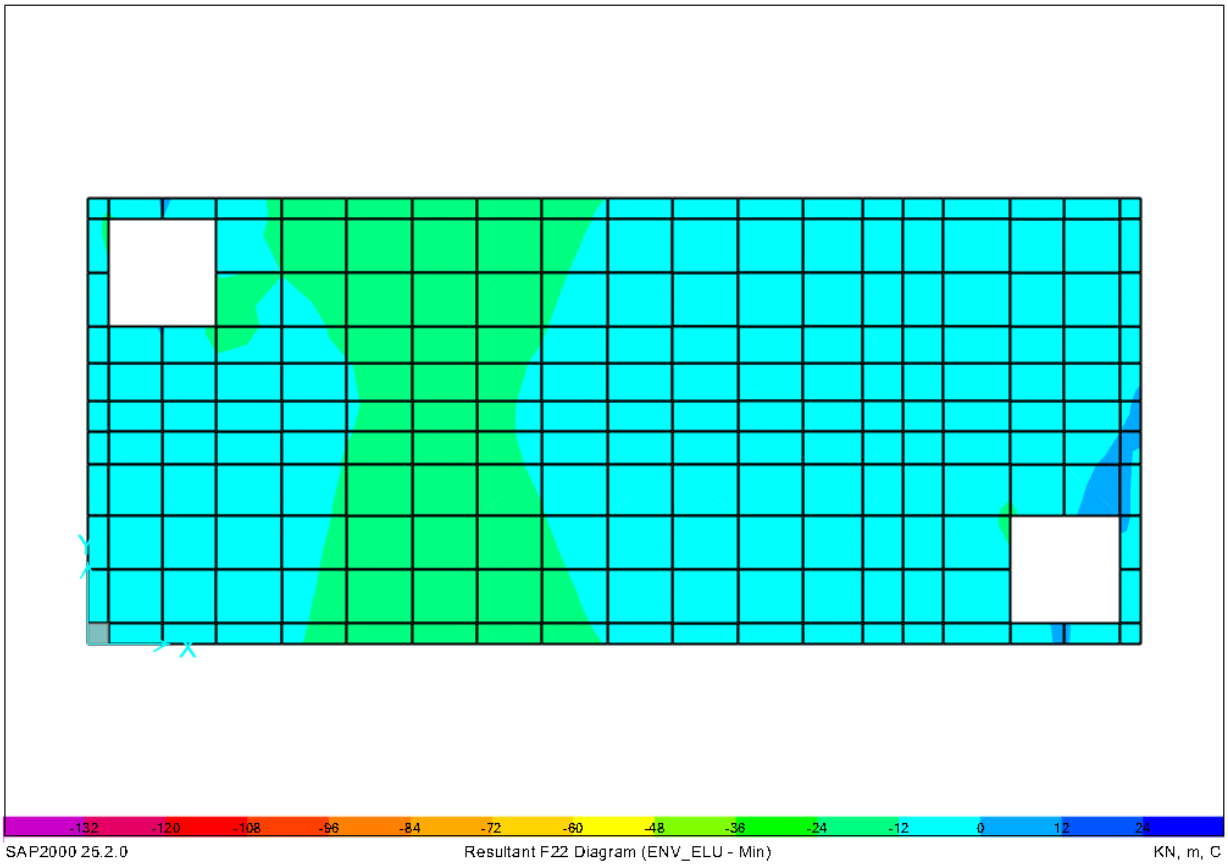

-45.0 -36.0 -27.0 -18.0 -9.0 0.0 9.0 18.0 27.0 36.0 45.0 54.0 63.0 72.0
SAP2000 25.2.0
Resultant V23 Diagram (ENV_ELU - Max)
KN, m, C

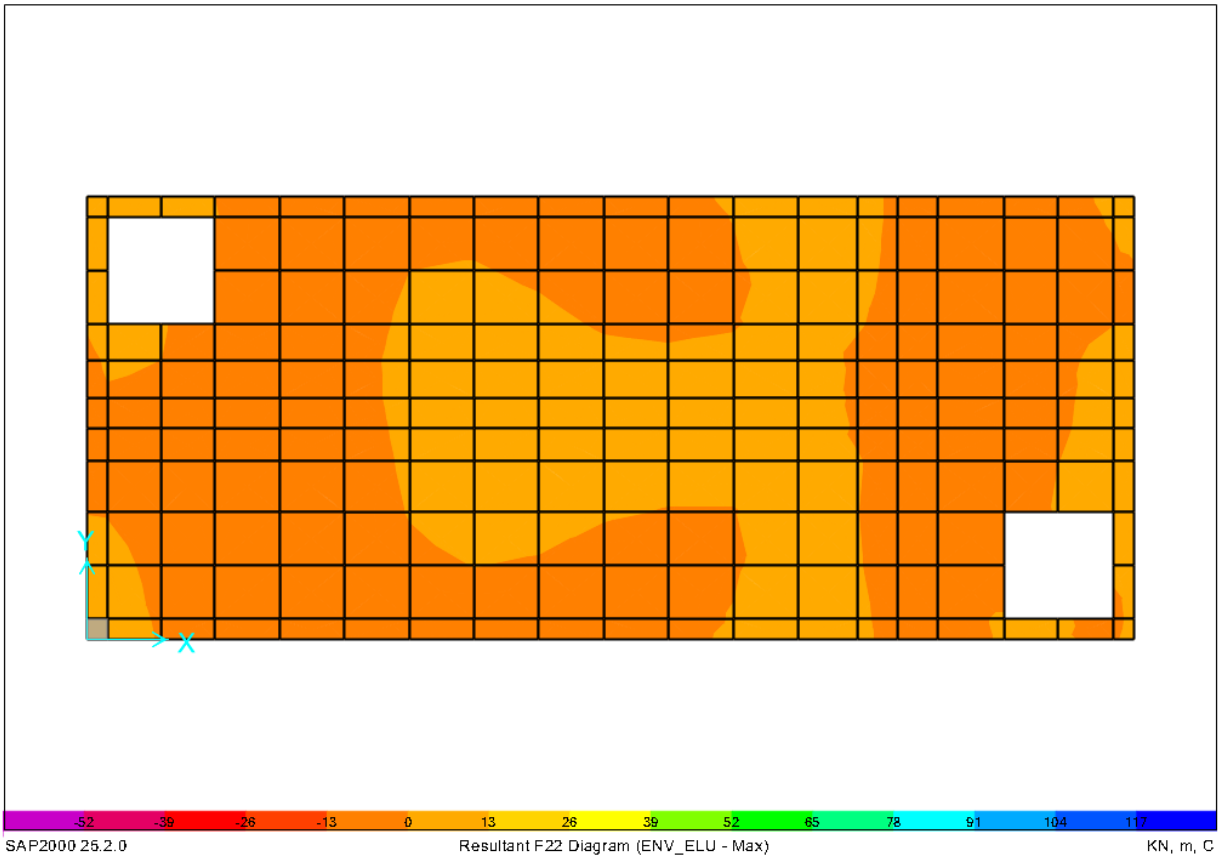
**Losa superior**

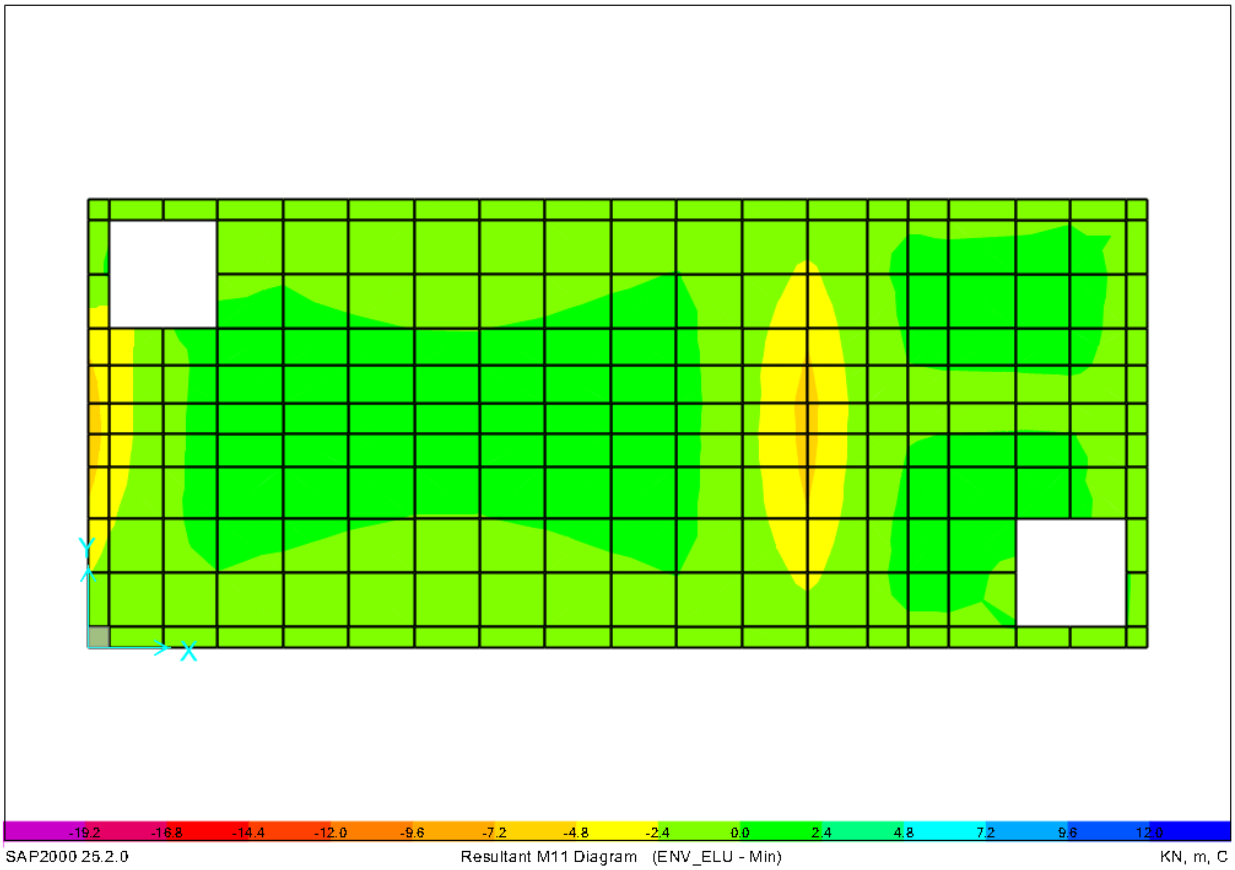
| LOSA SUPERIOR - LRFD RESULTADOS | | | | | |
|---|---|---|---|---|---|
| | $F_{11}$ (kN) | $M_{11}$ (kNm) | $F_{22}$ (kN) | $M_{22}$ (kNm) | Vmax (kN) |
| **ELU (min)** | -20,9 | -8,0 | -19,62 | -9,79 | 0,05 |
| **ELU (max)** | 14,7 | 5,15 | 13,55 | 6,41 | 23,08 |

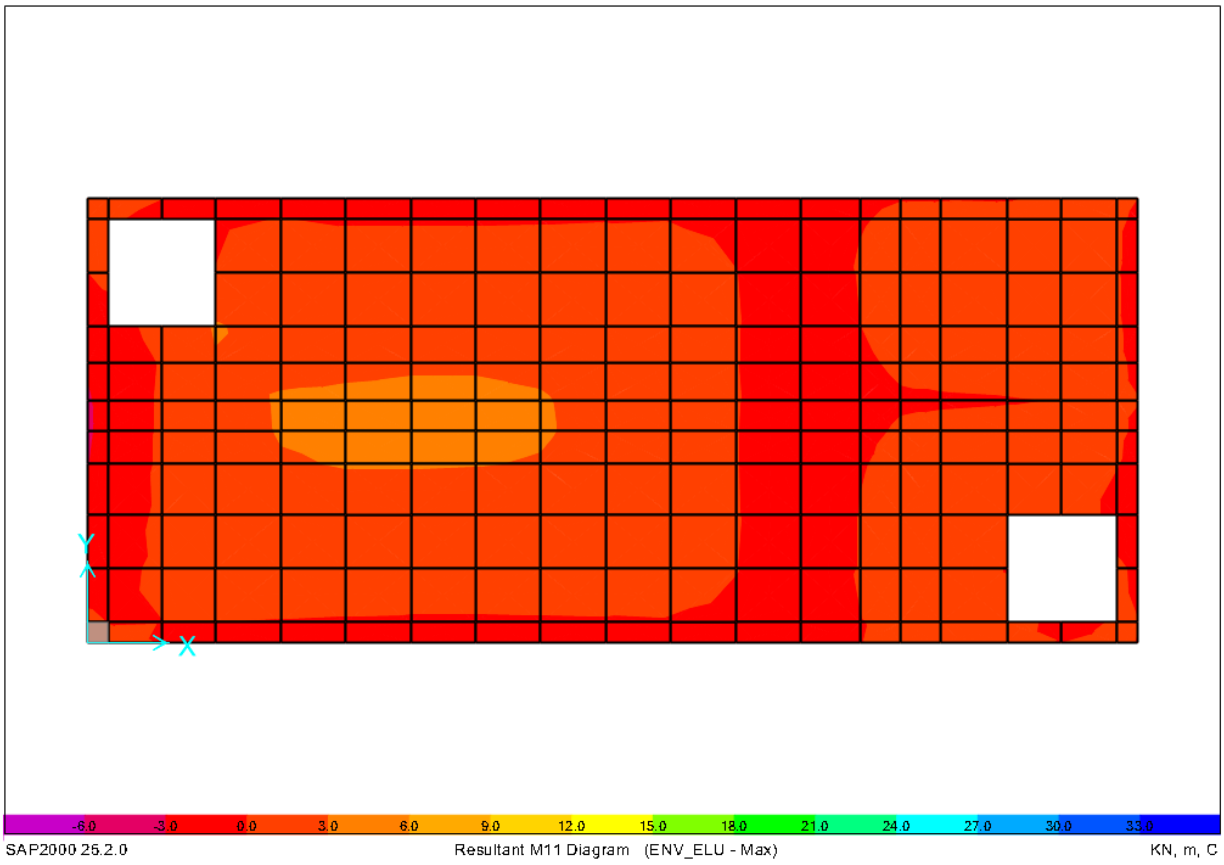


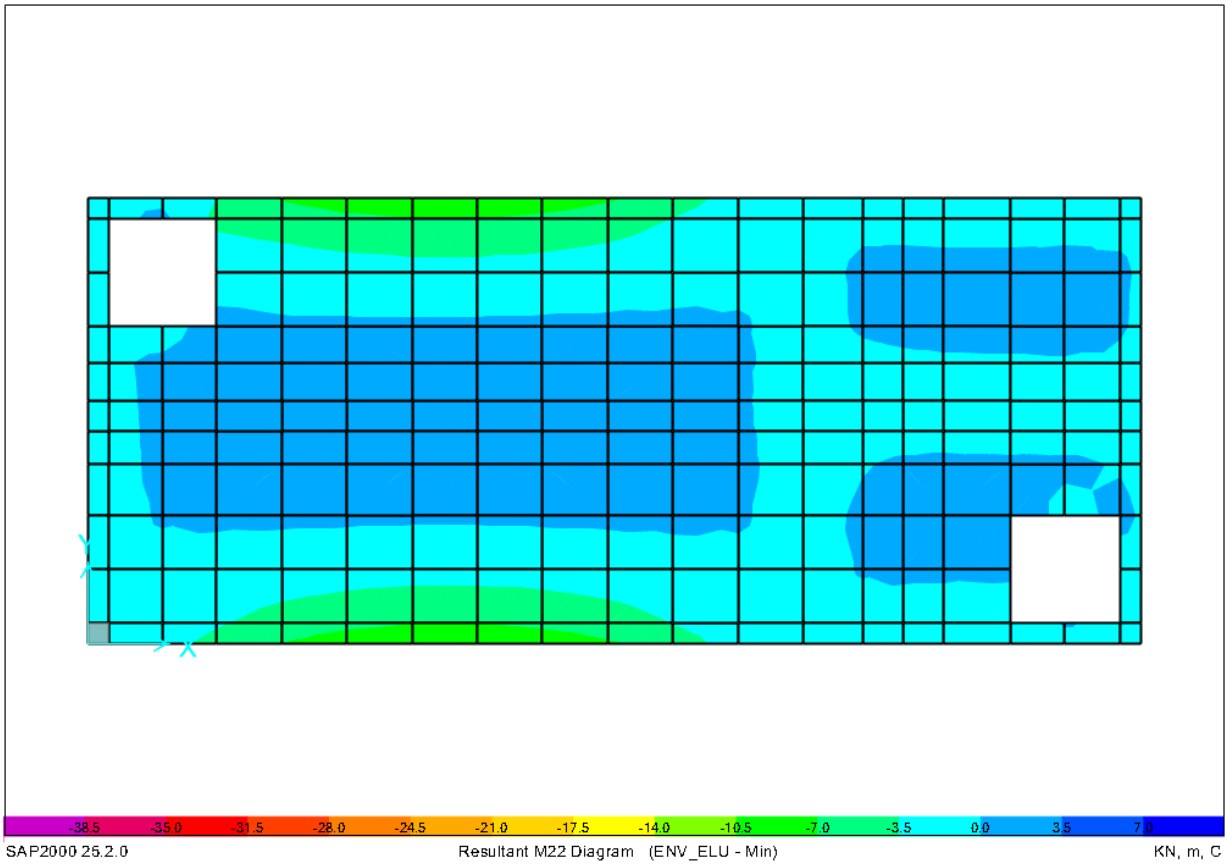

-26
-13
0
13
26
39
52
65
78
91
104
117
130
143
SAP2000 25.2.0
Resultant F11 Diagram (ENV_ELU - Max)
KN, m, C

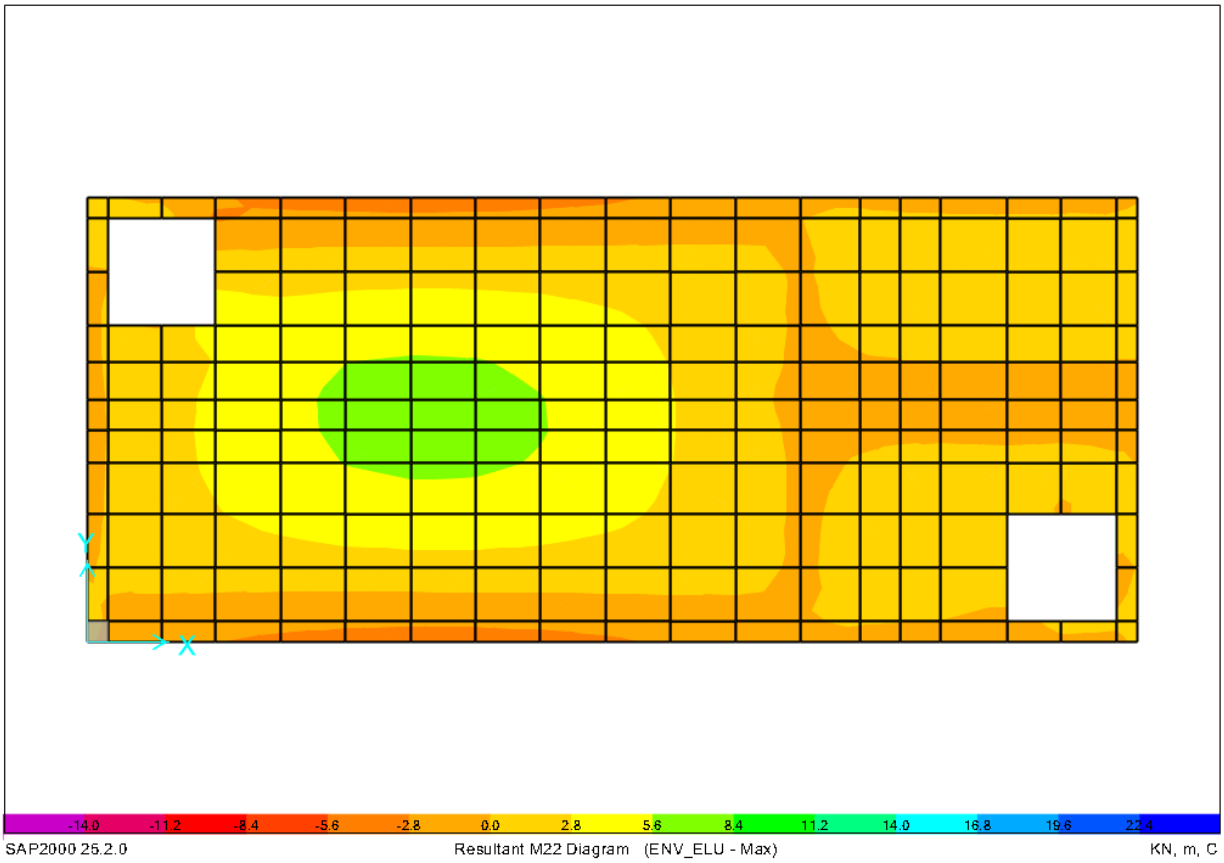

-132
-120
-108
-96
-84
-72
-60
-48
-36
-24
-12
0
12
24
SAP2000 25.2.0
Resultant F22 Diagram (ENV_ELU - Min)
KN, m, C

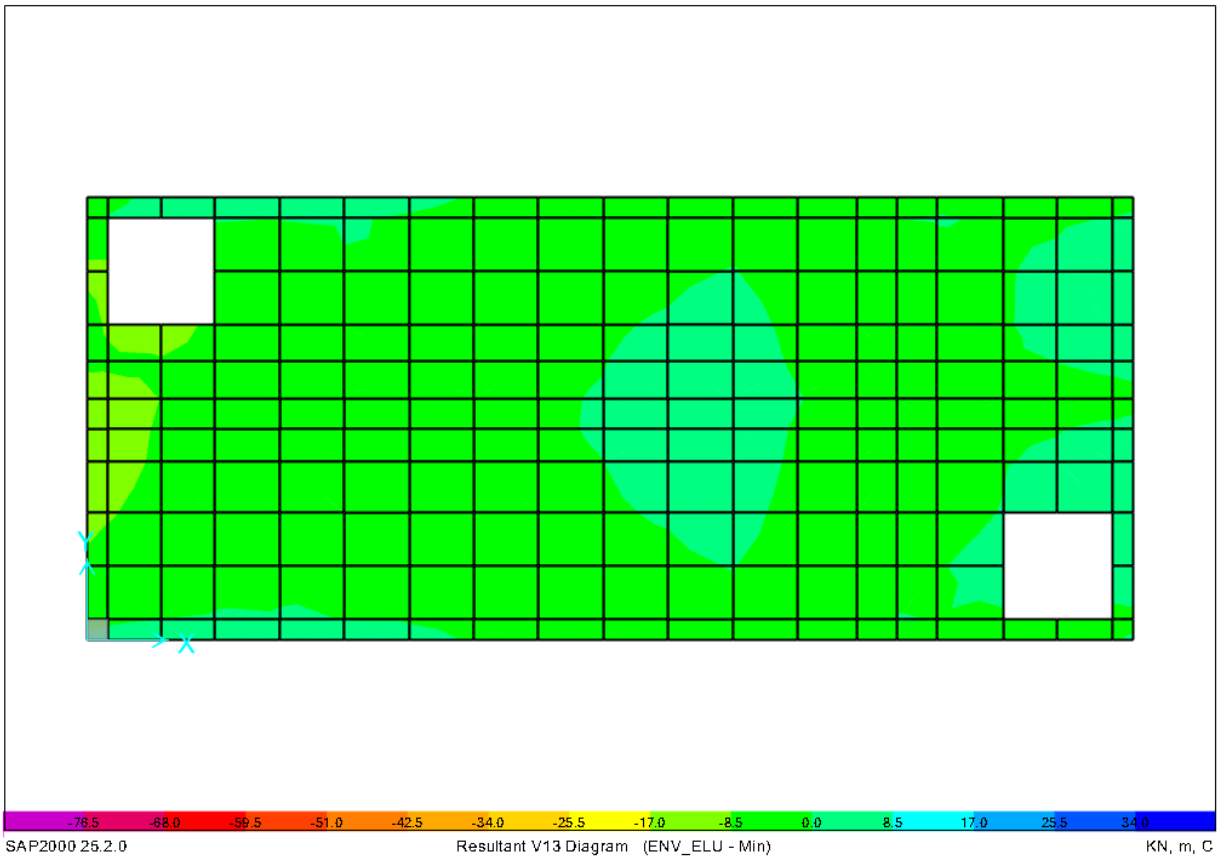

-52 -39 -26 -13 0 13 26 39 52 65 78 91 104 117
SAP2000 25.2.0
Resultant F22 Diagram (ENV_ELU - Max)
KN, m, C

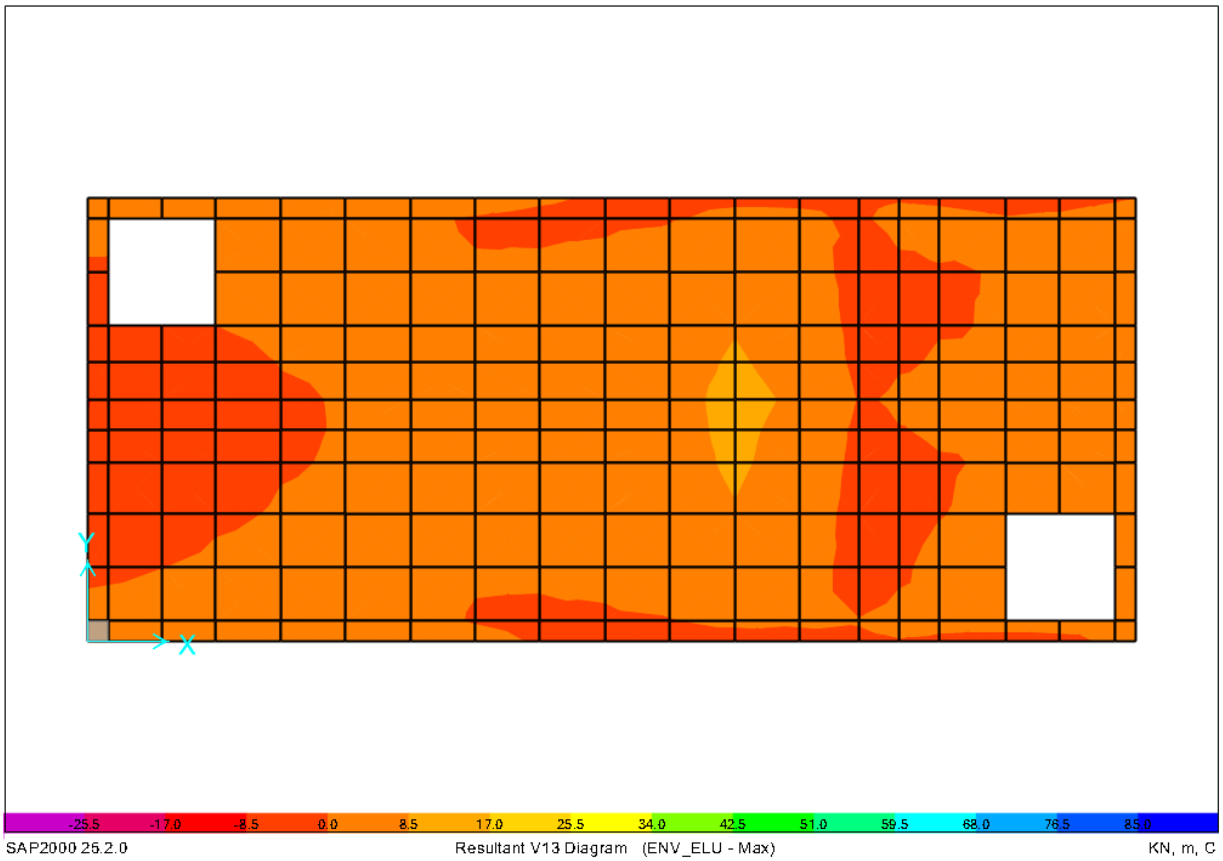

-19.2 -16.8 -14.4 -12.0 -9.6 -7.2 -4.8 -2.4 0.0 2.4 4.8 7.2 9.6 12.0
SAP2000 25.2.0
Resultant M11 Diagram (ENV_ELU - Min)
KN, m, C

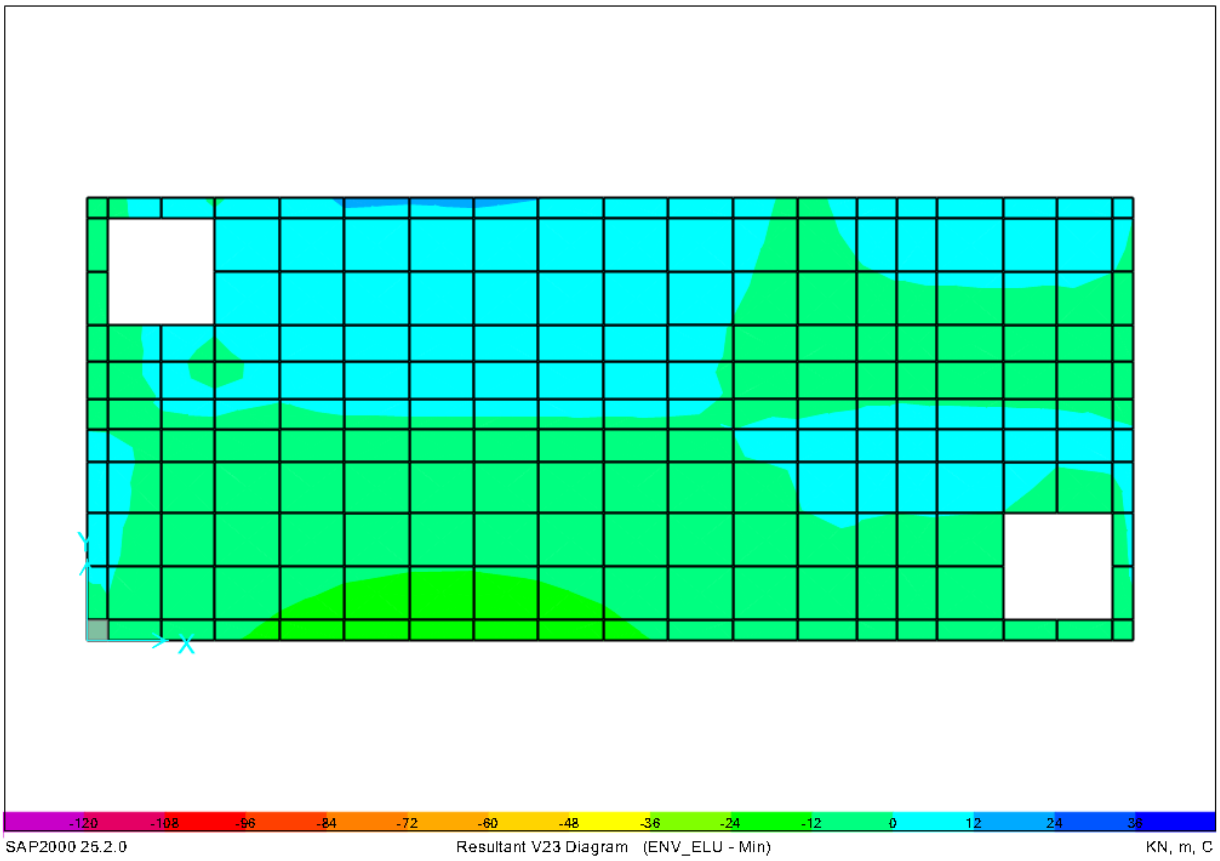

-6.0 -3.0 0.0 3.0 6.0 9.0 12.0 15.0 18.0 21.0 24.0 27.0 30.0 33.0
SAP2000 25.2.0
Resultant M11 Diagram (ENV_ELU - Max)
KN, m, C

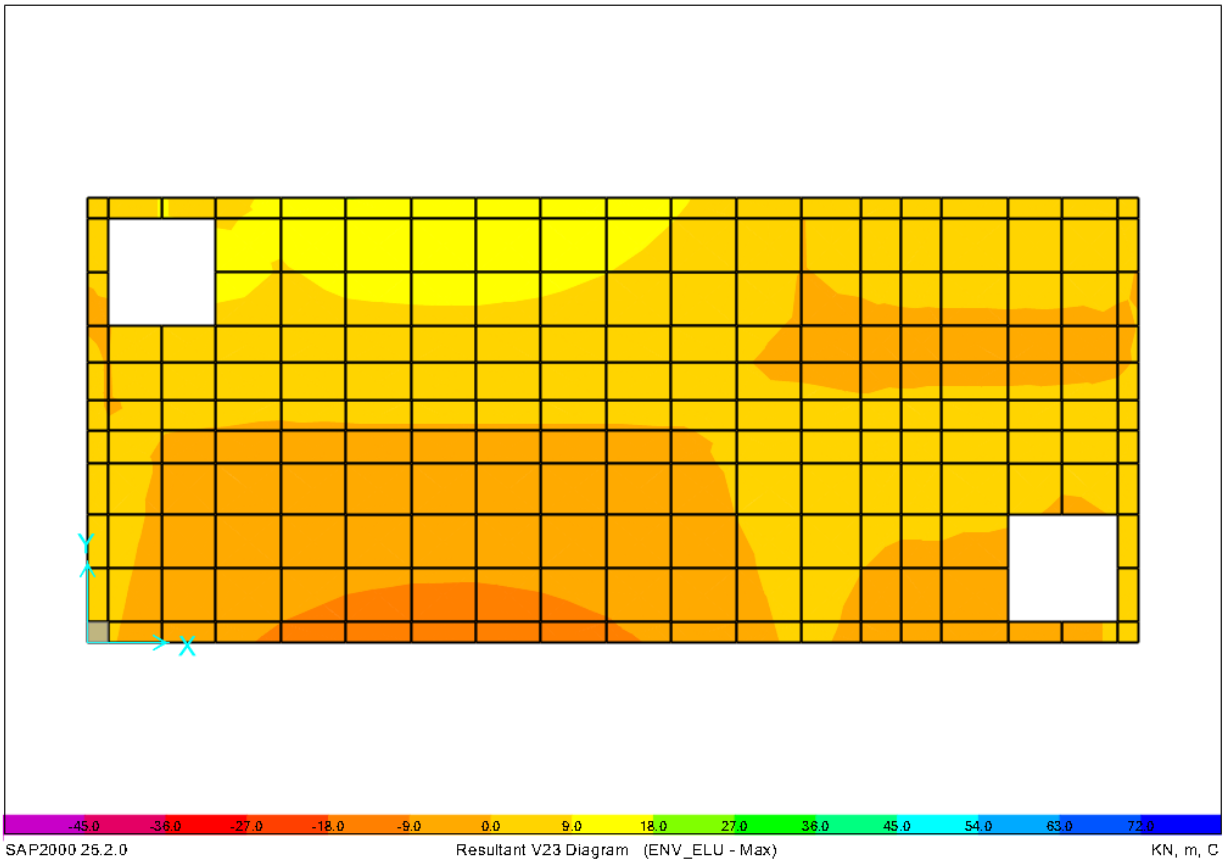

-38.5 -35.0 -31.5 -28.0 -24.5 -21.0 -17.5 -14.0 -10.5 -7.0 -3.5 0.0 3.5 7.0
SAP2000 25.2.0
Resultant M22 Diagram (ENV_ELU - Min)
KN, m, C


-14.0 -11.2 -8.4 -5.6 -2.8 0.0 2.8 5.6 8.4 11.2 14.0 16.8 19.6 22.4
SAP2000 25.2.0
Resultant M22 Diagram (ENV_ELU - Max)
KN, m, C


-76.5 -68.0 -59.5 -51.0 -42.5 -34.0 -25.5 -17.0 -8.5 0.0 8.5 17.0 25.5 34.0
SAP2000 25.2.0
Resultant V13 Diagram (ENV_ELU - Min)
KN, m, C


-25.5
-17.0
-8.5
0.0
8.5
17.0
25.5
34.0
42.5
51.0
59.5
68.0
76.5
85.0
SAP2000 25.2.0
Resultant V13 Diagram (ENV_ELU - Max)
KN, m, C


-120
-108
-96
-84
-72
-60
-48
-36
-24
-12
0
12
24
36
SAP2000 25.2.0
Resultant V23 Diagram (ENV_ELU - Min)
KN, m, C


Y
X
-45.0
-36.0
-27.0
-18.0
-9.0
0.0
9.0
18.0
27.0
36.0
45.0
54.0
63.0
72.0
SAP2000 25.2.0
Resultant V23 Diagram (ENV_ELU - Max)
KN, m, C

### 3.10.4 Verificaciones Estado Límite Último (ELU)

#### Losa base inferior

Se propone el siguiente armado:

| ARMADO LOSA BASE INFERIOR | | |
|---|---|---|
| Armadura longitudinal/transversal (cara superior) | Armadura longitudinal/transversal (cara inferior) | Armadura de cortante |
| Ø16@200mm (10.05cm$^2$/m) | Ø16@200mm (10.05cm$^2$/m) | No requerida |

| FLEXURE REINFORCEMENT CALCULATION | | |
|---|---|---|
| REF: EN-1992-1-1 | | |
| **Section inputs & material** | | |
| Flexure design moment | $M_d$ (KNm) | 32.13 |
| Section width | b (mm) | 1000 |
| Section heigth | h(mm) | 600 |
| Minimum cover | r (mm) | 50 |
| Effective section heigth | d (mm) | 542 |
| Specified compressive strength of concrete | $f_{ck}$(N/mm$^2$) | 25 |
| Coeff. for long term effects in compressive strength (chapter 3.1.6 EN-1992-1-1) | $a_{cc}$ | 0.85 |
| Partial factor for concrete, table 2.1N | $\gamma_C$ | 1.5 |
| Design value of concrete compressive strength $f_{cd} = \alpha_{cc} f_{ck} / \gamma_C$ | $f_{cd}$ (N/mm$^2$) | 14.17 |
| Mean tensile strength (according to table 3.1 EN 1992-1-1) | $f_{ctm}$ (N/mm$^2$) | 2.6 |
| Specified yield strength of reinforcement | $f_{yk}$ (N/mm$^2$) | 500 |
| Partial factor for reinforcing, table 2.1N | $\gamma_S$ | 1.15 |
| Design yield strength of reinforcement | $f_{yd}$ (N/mm$^2$) | 435 |
| Modulus of elasticity of reinforcement | $E_s$ (N/mm$^2$) | 200000 |
| for $f_{ck}$ < 50MPa (3.19) | l | 0.8 |
| for $f_{ck}$ < 50MPa (3.21) | h | 1.00 |
| | $k_1$ | 0.44 |
| | $k_2$ | 1.25 |
| (for $f_{ck}$ < 50MPa )Ultimate concrete strain (table 3.1) | $e_{cu2}$ | 0.0035 |
| Ratio of the redistributed moment to the elastic bending moment | d | 1.00 |
| | $(x/d)_{lim}$ | 0.45 |
| Strain in concrete, max value (table 3.1) | $\varepsilon_c$ (max) | 0.0035 |
| Strain in concrete, min value (table 3.1) | $\varepsilon_c$ (min) | 0.00175 |
| Normalized moment | m | 0.0077 |
| Normalized section capacity as a singly reinforced beam | $m_{lim}$ | 0.2942 |
| | $x_{lim}$(mm) | 242.8160 |
| **Reinforcement** | | |
| | If m<$m_{lim}$: | **APPLIED** |
| Normalized steel ratio | w | 0.00775 |
| Longitudinal reinforcement area in tensile | $A_s$ (cm$^2$) | 1.369 |
| | If m>$m_{lim}$: | **NOT APPLIED** |
| | $w_{lim}$ | 0.3584 |
| Depth to the compression steel, measured from the concrete compression face | d´ (mm) | 58 |
| | w´ | -0.320781398 |
| | w | 0.037618602 |
| Stress in the compression steel | $f_s$´ (N/mm$^2$) | 434.7826087 |
| Longitudinal reinforcement area in compression | $A_s$´(cm$^2$) (up for $M_d$+) | Not required |
| Longitudinal reinforcement area in tensile | $A_s$ (cm$^2$) (bottom for $M_d$+) | 6.64 |

| | | |
|---|---|---|
| OVERALL Required Md | $A_s'$ ($cm^2$) (up for $M_d$ +) | 0.000 |
| OVERALL Required Md | $A_s$ ($cm^2$)(bottom for $M_d$ +) | 1.369 |
| The tensile is in both faces | T (kN) | 142 |
| Shear effort (6.2.3 (7), EN-1992-1-1) | $V_E$ (kN) | 0 |
| Reinf. in each face | $A_s$ ($cm^2$) | 1.633 |
| Total necessary reinf. In top face | $A_s$ ($cm^2$)(TOTAL) | **1.63** |
| Total necessary reinf. In low face (tensile face) | $A_s$ ($cm^2$)(TOTAL) | **3.00** |

**Disposed reinforcement:**

| | | |
|---|---|---|
| Diameter of bar | ϕ (mm) | 16 |
| Bar spacing | s (m) | 200 |
| Nº of reinf.layers | n | 1 |
| Area provided | A ($cm^2$) | 10.053 |
| | additional reinforcement | |
| Diameter of bar | ϕ (mm) | 0 |
| Bar spacing | s (m) | 200 |
| Area provided | A ($cm^2$) | 0.000 |
| | $A_{total}$ ($cm^2$) | 10.053 |
| | **OK Flexure** | **30%** |
| | - | - |
| - | - | - |

**Minimum reinforcement EN-1992-1-1**

| | | |
|---|---|---|
| | Section type | SLAB/FOUNDATION |
| | minimum ratio | **0.001352** |
| Minimum reinforcement for each face | $As_{min}$ ($cm^2$) | 7.328 |
| - | - | - |
| Reinforcement provided | $A_{total}$ ($cm^2$) | **10.05** |
| | **OK Minimum reinforcement** | **73%** |

**Maximum reinforcement EN-1992-1-1**

| | | |
|---|---|---|
| | maximum ratio | **0.040** |
| | $As_{max}$ ($cm^2$) | 240 |
| | **OK maximum reinforcement** | **4%** |
| | $s_{max}$ (mm) | 400 |
| | | **OK** |

| SHEAR REINFORCEMENT CALCULATION | | | |
|---|---|---|---|
| | | | EN 1992-1 AND EN 1992-2 |
| **Geometry and materials** | | | |
| Overall depth of the cross section | $h$ | [m] | 0.60 |
| Distance from the tension fiber to the centroid of the tensile reinforcement | $d'$ | [m] | 0.05 |
| Effective depth | $d$ | [m] | 0.55 |
| Smallest width of the cross section in the tensile area | $b_w$ | [m] | 1.00 |
| Number of grouted metal ducts in the web | $N_{ducts}$ | | 0 |
| Diamenter of the duct | $\phi_{duct}$ | [mm] | 0 |
| Nominal web thickness considering the PT ducts | $b_{w,nom}$ | [m] | 1.00 |
| Characteristic compressive cylinder strength of concrete at 28 days | $f_{ck}$ | [MPa] | 25 |
| Partial factor for concrete | $\gamma_c$ | | 1.2 |
| Characteristic yield strength of shear reinforcement | $f_{ywk}$ | [MPa] | 500 |
| Partial factor for reinforcing steel | $\gamma_s$ | | 1 |
| Area of tensile reinforcement | $A_{sl}$ | [$cm^2$] | 10.05 |
| Area of concrete cross section | $A_c$ | [$m^2$] | 0.60 |
| **Forces** | | | |
| Axial force in the cross section due to loading or the acing effect of prestressing ($N_{Ed}$ > 0 for compression) | $N_{Ed}$ | [kN] | -127.2 |
| Design value of the applied shear force | $V_{Ed}$ | [kN] | 177.6 |
| **Members not requiring shear reinforcement** | | | |
| | $k$ | | 1.6 |
| | $\rho_l$ | | 0.0018 |
| | $\sigma_{cp}$ | [MPa] | -0.21 |
| | $C_{Rd,c}$ | | 0.15 |
| | $v_{min}$ | [MPa] | 0.36 |
| | $k_1$ | | 0.15 |
| Design value for the shear resistance | **$V_{Rd,c}$** | **[kN]** | **202.0** |

## Muros

Se propone el siguiente armado:

| ARMADO MUROS | | |
|---|---|---|
| Armadura longitudinal/transversal (cara externa) | Armadura longitudinal/transversal (cara interna) | Armadura de cortante |
| Ø12@200mm (5,65cm²/m) | Ø12@200mm (5,65cm²/m) | No requiere armado a cortante |

| FLEXURE REINFORCEMENT CALCULATION | | |
|---|---|---|
| REF: EN-1992-1-1 | | |
| **Section inputs & material** | | |
| Flexure design moment | $M_d$ (KNm) | 33 |
| Section width | b (mm) | 1000 |
| Section heigth | h(mm) | 300 |
| Minimum cover | r (mm) | 50 |
| Effective section heigth | d (mm) | 244 |
| Specified compressive strength of concrete | $f_{ck}$(N/mm²) | 25 |
| Coeff. for long term effects in compressive strength (chapter 3.1.6 EN-1992-1-1) | $a_{cc}$ | 0.85 |
| Partial factor for concrete, table 2.1N | $\gamma_c$ | 1.5 |
| Design value of concrete compressive strength $f_{cd} = \alpha_{cc} f_{ck} / \gamma_C$ | $f_{cd}$ (N/mm²) | 14.17 |
| Mean tensile strength (according to table 3.1 EN 1992-1-1) | $f_{ctm}$ (N/mm²) | 2.6 |
| Specified yield strength of reinforcement | $f_{yk}$ (N/mm²) | 500 |
| Partial factor for reinforcing, table 2.1N | $\gamma_s$ | 1.15 |
| Design yield strength of reinforcement | $f_{yd}$ (N/mm²) | 435 |
| Modulus of elasticity of reinforcement | $E_s$ (N/mm²) | 200000 |
| for $f_{ck}$ < 50MPa (3.19) | l | 0.8 |
| for $f_{ck}$ < 50MPa (3.21) | h | 1.00 |
| | $k_1$ | 0.44 |
| | $k_2$ | 1.25 |
| (for $f_{ck}$ < 50MPa )Ultimate concrete strain (table 3.1) | $e_{cu2}$ | 0.0035 |
| Ratio of the redistributed moment to the elastic bending moment | d | 1.00 |
| | $(x/d)_{lim}$ | 0.45 |
| Strain in concrete, max value (table 3.1) | $\varepsilon_c$ (max) | 0.0035 |
| Strain in concrete, min value (table 3.1) | $\varepsilon_c$ (min) | 0.00175 |
| Normalized moment | m | 0.0391 |
| Normalized section capacity as a singly reinforced beam | $m_{lim}$ | 0.2942 |
| | $x_{lim}$(mm) | 109.3120 |
| **Reinforcement** | | |
| | If m<$m_{lim}$: | **APPLIED** |
| Normalized steel ratio | w | 0.03992 |
| Longitudinal reinforcement area in tensile | $A_s$ (cm²) | 3.174 |
| | If m>$m_{lim}$: | **NOT APPLIED** |
| | $w_{lim}$ | 0.3584 |
| Depth to the compression steel, measured from the concrete compression face | d´ (mm) | 56 |
| | w´ | -0.331020543 |
| | w | 0.027379457 |
| Stress in the compression steel | $f_s$´ (N/mm²) | 341.3934426 |
| Longitudinal reinforcement area in compression | $A_s$´(cm²) (up for $M_d$+) | Not required |
| Longitudinal reinforcement area in tensile | $A_s$ (cm²) (bottom for $M_d$+) | 2.18 |

| | | |
|---|---|---|
| OVERALL Required Md | $A_s'$ ($cm^2$) (up for $M_d$ +) | 0.000 |
| OVERALL Required Md | $A_s$ ($cm^2$)(bottom for $M_d$ +) | 3.174 |
| The tensile is in both faces | T (kN) | 87 |
| Shear effort (6.2.3 (7), EN-1992-1-1) | $V_E$ (kN) | 0 |
| Reinf. in each face | $A_s$ ($cm^2$) | 1.001 |
| Total necessary reinf. In top face | $A_s$ ($cm^2$)(TOTAL) | **1.00** |
| Total necessary reinf. In low face (tensile face) | $A_s$ ($cm^2$)(TOTAL) | **4.17** |

**Disposed reinforcement:**

| | | |
|---|---|---|
| Diameter of bar | ϕ (mm) | 12 |
| Bar spacing | s (m) | 200 |
| Nº of reinf.layers | n | 1 |
| Area provided | A ($cm^2$) | 5.655 |
| | additional reinforcement | |
| Diameter of bar | ϕ (mm) | 0 |
| Bar spacing | s (m) | 200 |
| Area provided | A ($cm^2$) | 0.000 |
| | $A_{total}$ ($cm^2$) | 5.655 |
| | **OK Flexure** | **74%** |
| | - | - |
| - | - | - |

**Minimum reinforcement EN-1992-1-1**

| | | |
|---|---|---|
| | Section type | WALL (horizontal) |
| | minimum ratio | **0.001600** |
| Minimum reinforcement for each face | $As_{min}$ ($cm^2$) | 3.904 |
| - | - | - |
| Reinforcement provided | $A_{total}$ ($cm^2$) | **5.65** |
| | **OK Minimum reinforcement** | **69%** |

**Maximum reinforcement EN-1992-1-1**

| | | |
|---|---|---|
| | maximum ratio | **0.040** |
| | $As_{max}$ ($cm^2$) | 120 |
| | **OK maximum reinforcement** | **5%** |
| | $s_{max}$ (mm) | 400 |
| | | **OK** |

| SHEAR REINFORCEMENT CALCULATION | | | |
|---|---|---|---|
| | | | EN 1992-1 AND EN 1992-2 |
| **Geometry and materials** | | | |
| Overall depth of the cross section | $h$ | [m] | 0.30 |
| Distance from the tension fiber to the centroid of the tensile reinforcement | $d'$ | [m] | 0.05 |
| Effective depth | $d$ | [m] | 0.25 |
| Smallest width of the cross section in the tensile area | $b_w$ | [m] | 1.00 |
| Number of grouted metal ducts in the web | $N_{ducts}$ | | 0 |
| Diamenter of the duct | $\phi_{duct}$ | [mm] | 0 |
| Nominal web thickness considering the PT ducts | $b_{w,nom}$ | [m] | 1.00 |
| Characteristic compressive cylinder strength of concrete at 28 days | $f_{ck}$ | [MPa] | 25 |
| Partial factor for concrete | $\gamma_c$ | | 1.2 |
| Characteristic yield strength of shear reinforcement | $f_{ywk}$ | [MPa] | 500 |
| Partial factor for reinforcing steel | $\gamma_s$ | | 1 |
| Area of tensile reinforcement | $A_{sl}$ | [$cm^2$] | 5.65 |
| Area of concrete cross section | $A_c$ | [$m^2$] | 0.30 |
| **Forces** | | | |
| Axial force in the cross section due to loading or the acing effect of prestressing ($N_{Ed}$ > 0 for compression) | $N_{Ed}$ | [kN] | -107.0 |
| Design value of the applied shear force | $V_{Ed}$ | [kN] | 108.0 |
| **Members not requiring shear reinforcement** | | | |
| | $k$ | | 1.9 |
| | $\rho_l$ | | 0.0023 |
| | $\sigma_{cp}$ | [MPa] | -0.36 |
| | $C_{Rd,c}$ | | 0.15 |
| | $v_{min}$ | [MPa] | 0.46 |
| | $k_1$ | | 0.15 |
| Design value for the shear resistance | **$V_{Rd,c}$** | **[kN]** | **113.2** |

## Losa superior

| ARMADO LOSA SUPERIOR | | |
|---|---|---|
| Armadura longitudinal/transversal (cara externa) | Armadura longitudinal/transversal (cara interna) | Armadura de cortante |
| Ø12@200mm (5,65cm²/m) | Ø12@200mm (5,65cm²/m) | No requiere armado a cortante |

| FLEXURE REINFORCEMENT CALCULATION | | |
|---|---|---|
| REF: EN-1992-1-1 | | |
| **Section inputs & material** | | |
| Flexure design moment | $M_d$ (KNm) | 10 |
| Section width | b (mm) | 1000 |
| Section heigth | h(mm) | 300 |
| Minimum cover | r (mm) | 50 |
| Effective section heigth | d (mm) | 244 |
| Specified compressive strength of concrete | $f_{ck}$(N/mm²) | 25 |
| Coeff. for long term effects in compressive strength (chapter 3.1.6 EN-1992-1-1) | $a_{cc}$ | 0.85 |
| Partial factor for concrete, table 2.1N | $\gamma_c$ | 1.5 |
| Design value of concrete compressive strength $f_{cd} = \alpha_{cc} f_{ck} / \gamma_C$ | $f_{cd}$ (N/mm²) | 14.17 |
| Mean tensile strength (according to table 3.1 EN 1992-1-1) | $f_{ctm}$ (N/mm²) | 2.6 |
| Specified yield strength of reinforcement | $f_{yk}$ (N/mm²) | 500 |
| Partial factor for reinforcing, table 2.1N | $\gamma_s$ | 1.15 |
| Design yield strength of reinforcement | $f_{yd}$ (N/mm²) | 435 |
| Modulus of elasticity of reinforcement | $E_s$ (N/mm²) | 200000 |
| for $f_{ck}$ < 50MPa (3.19) | l | 0.8 |
| for $f_{ck}$ < 50MPa (3.21) | h | 1.00 |
| | $k_1$ | 0.44 |
| | $k_2$ | 1.25 |
| (for $f_{ck}$ < 50MPa )Ultimate concrete strain (table 3.1) | $e_{cu2}$ | 0.0035 |
| Ratio of the redistributed moment to the elastic bending moment | d | 1.00 |
| | $(x/d)_{lim}$ | 0.45 |
| Strain in concrete, max value (table 3.1) | $\varepsilon_c$ (max) | 0.0035 |
| Strain in concrete, min value (table 3.1) | $\varepsilon_c$ (min) | 0.00175 |
| Normalized moment | m | 0.0119 |
| Normalized section capacity as a singly reinforced beam | $m_{lim}$ | 0.2942 |
| | $x_{lim}$(mm) | 109.3120 |
| **Reinforcement** | | |
| | If m<$m_{lim}$: | **APPLIED** |
| Normalized steel ratio | w | 0.01193 |
| Longitudinal reinforcement area in tensile | $A_s$ (cm²) | 0.948 |
| | If m>$m_{lim}$: | **NOT APPLIED** |
| | $w_{lim}$ | 0.3584 |
| Depth to the compression steel, measured from the concrete compression face | d´ (mm) | 56 |
| | w´ | -0.366413145 |
| | w | -0.008013145 |
| Stress in the compression steel | $f_s$´ (N/mm²) | 341.3934426 |
| Longitudinal reinforcement area in compression | $A_s$´(cm²) (up for $M_d$+) | Not required |
| Longitudinal reinforcement area in tensile | $A_s$ (cm²) (bottom for $M_d$+) | -0.64 |

| | | |
|---|---|---|
| OVERALL Required Md | $A_s'$ ($cm^2$) (up for $M_d$ +) | 0.000 |
| OVERALL Required Md | $A_s$ ($cm^2$)(bottom for $M_d$ +) | 0.948 |
| The tensile is in both faces | T (kN) | 18 |
| Shear effort (6.2.3 (7), EN-1992-1-1) | $V_E$ (kN) | 0 |
| Reinf. in each face | $A_s$ ($cm^2$) | 0.207 |
| Total necessary reinf. In top face | $A_s$ ($cm^2$)(TOTAL) | **0.21** |
| Total necessary reinf. In low face (tensile face) | $A_s$ ($cm^2$)(TOTAL) | **1.16** |

**Disposed reinforcement:**

| | | |
|---|---|---|
| Diameter of bar | ϕ (mm) | 12 |
| Bar spacing | s (m) | 200 |
| Nº of reinf.layers | n | 1 |
| Area provided | A ($cm^2$) | 5.655 |
| | additional reinforcement | |
| Diameter of bar | ϕ (mm) | 0 |
| Bar spacing | s (m) | 200 |
| Area provided | A ($cm^2$) | 0.000 |
| | $A_{total}$ ($cm^2$) | 5.655 |
| | **OK Flexure** | **20%** |
| | - | - |
| - | - | - |

**Minimum reinforcement EN-1992-1-1**

| | | |
|---|---|---|
| | Section type | SLAB/FOUNDATION |
| | minimum ratio | **0.001352** |
| Minimum reinforcement for each face | $As_{min}$ ($cm^2$) | 3.299 |
| - | - | - |
| Reinforcement provided | $A_{total}$ ($cm^2$) | **5.65** |
| | **OK Minimum reinforcement** | **58%** |

**Maximum reinforcement EN-1992-1-1**

| | | |
|---|---|---|
| | maximum ratio | **0.040** |
| | $As_{max}$ ($cm^2$) | 120 |
| | **OK maximum reinforcement** | **5%** |
| | $s_{max}$ (mm) | 400 |
| | | **OK** |

| SHEAR REINFORCEMENT CALCULATION | | | |
|---|---|---|---|
| | | | EN 1992-1 AND EN 1992-2 |
| **Geometry and materials** | | | |
| Overall depth of the cross section | h | [m] | 0.30 |
| Distance from the tension fiber to the centroid of the tensile reinforcement | d' | [m] | 0.05 |
| Effective depth | d | [m] | 0.25 |
| Smallest width of the cross section in the tensile area | $b_w$ | [m] | 1.00 |
| Number of grouted metal ducts in the web | $N_{ducts}$ | | 0 |
| Diamenter of the duct | $\phi_{duct}$ | [mm] | 0 |
| Nominal web thickness considering the PT ducts | $b_{w,nom}$ | [m] | 1.00 |
| Characteristic compressive cylinder strength of concrete at 28 days | $f_{ck}$ | [MPa] | 25 |
| Partial factor for concrete | $\gamma_c$ | | 1.2 |
| Characteristic yield strength of shear reinforcement | $f_{ywk}$ | [MPa] | 500 |
| Partial factor for reinforcing steel | $\gamma_s$ | | 1 |
| Area of tensile reinforcement | $A_{sl}$ | [$cm^2$] | 5.65 |
| Area of concrete cross section | $A_c$ | [$m^2$] | 0.30 |
| **Forces** | | | |
| Axial force in the cross section due to loading or the acing effect of prestressing ($N_{Ed}$ > 0 for compression) | $N_{Ed}$ | [kN] | -19.3 |
| Design value of the applied shear force | $V_{Ed}$ | [kN] | 16.0 |
| **Members not requiring shear reinforcement** | | | |
| | k | | 1.9 |
| | $\rho_l$ | | 0.0023 |
| | $\sigma_{cp}$ | [MPa] | -0.06 |
| | $C_{Rd,c}$ | | 0.15 |
| | $v_{min}$ | [MPa] | 0.46 |
| | $k_1$ | | 0.15 |
| Design value for the shear resistance | **$V_{Rd,c}$** | **[kN]** | **124.1** |

### 3.10.5 Verificación Estado Límite Servicio (ELS)

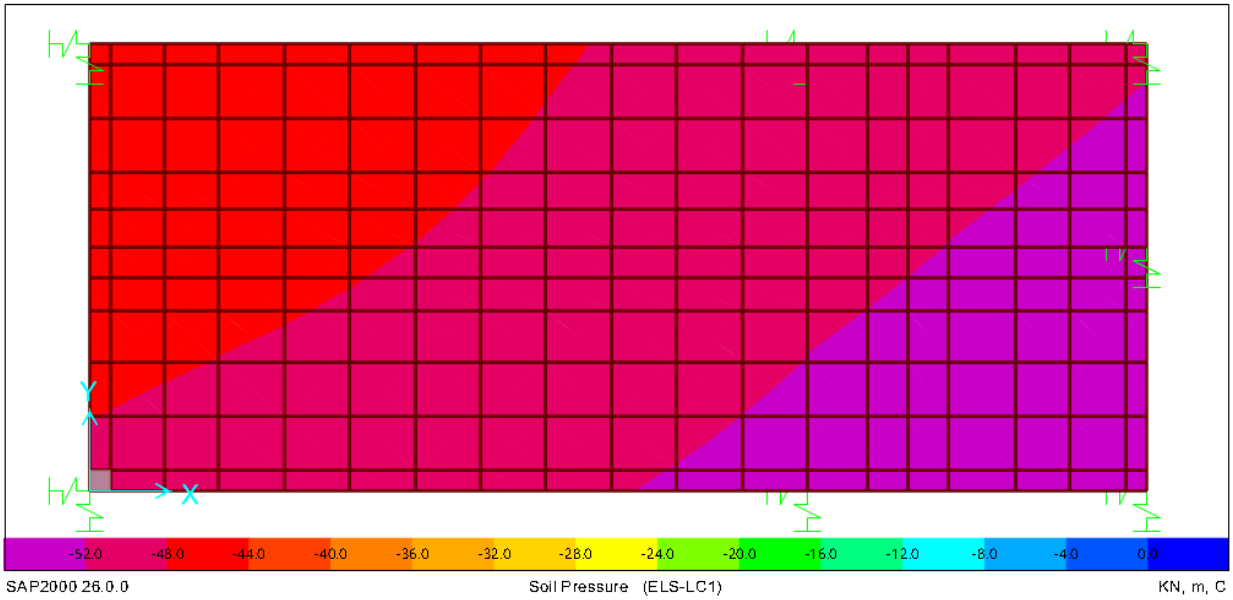
#### Comprobación abertura máxima de fisura

Se ha realizado una comprobación del máximo momento de fisuración por cada sección. A continuación, se proporciona un resumen del momento máximo resistente y del momento solicitado por tipo de sección:

| COMPROBACIÓN A FISURACIÓN | | |
|---|---|---|
| **Sección** | **$M_d$ (kNm)** | **$M_R$ (kNm)** |
| Losa base inferior | 27 | 192,60 |
| Muros | 23 | 48,15 |
| Losa superior | 3,7 | 48,15 |

#### Tensión máxima transmitida al terreno

La tensión máxima transmitida al terreno es de 52 kN/m².




## 3.11 Modelo de cálculo. Arqueta de reunión

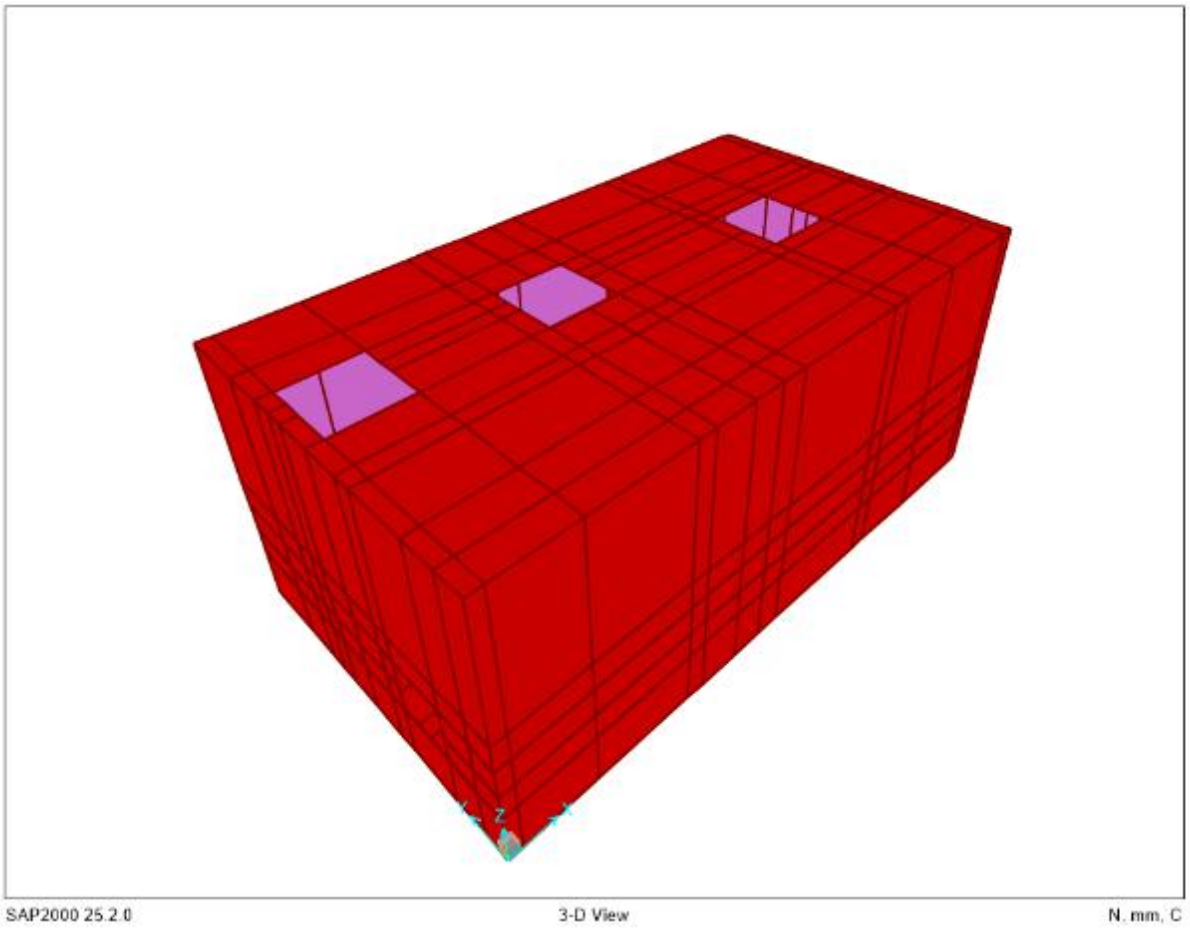
El cálculo estructural se realiza acorde al método global de análisis utilizado para cálculo de fuerzas y momentos internos de los miembros, mediante un modelo tridimensional, con el software de diseño estructural SAP2000 v25.1.0.

Este software utiliza el método de análisis elástico que puede usarse en todos los casos. El programa se basa en técnicas de cálculo matricial y elementos finitos bajo las habituales hipótesis de elasticidad lineal:

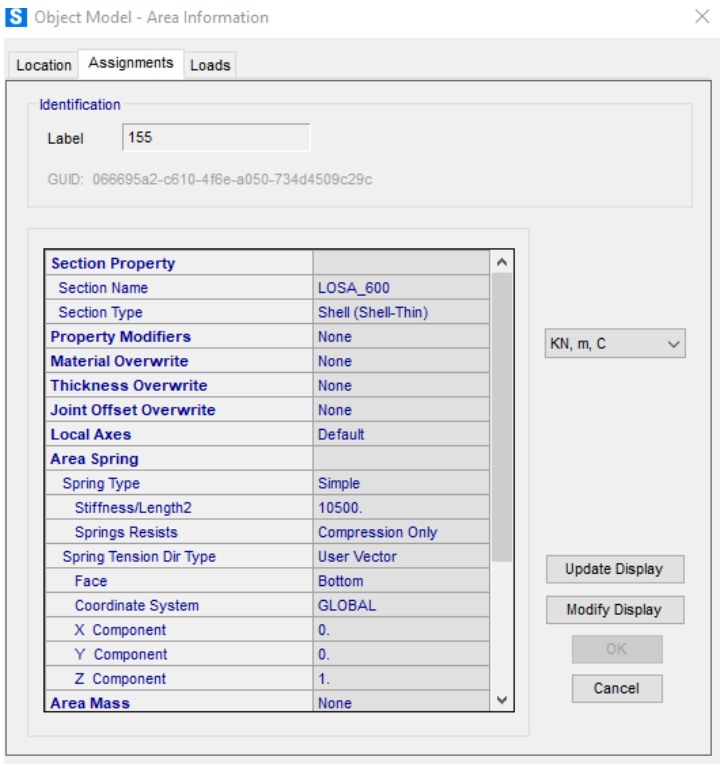
- Proporcionalidad entre tensiones y deformaciones.
- Compatibilidad de elementos estructurales.
- Balance estático local y global de cada una de las partes de la estructura

### 3.11.1 Geometría

Los muros y losas que forman la arqueta se representan mediante elementos tipo «Shell» de distintos espesores.



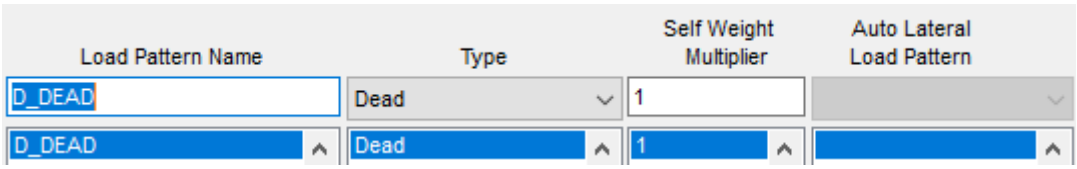

El módulo de balasto considerado según el terreno en la cimentación es de 10500 kN/m$^3$.



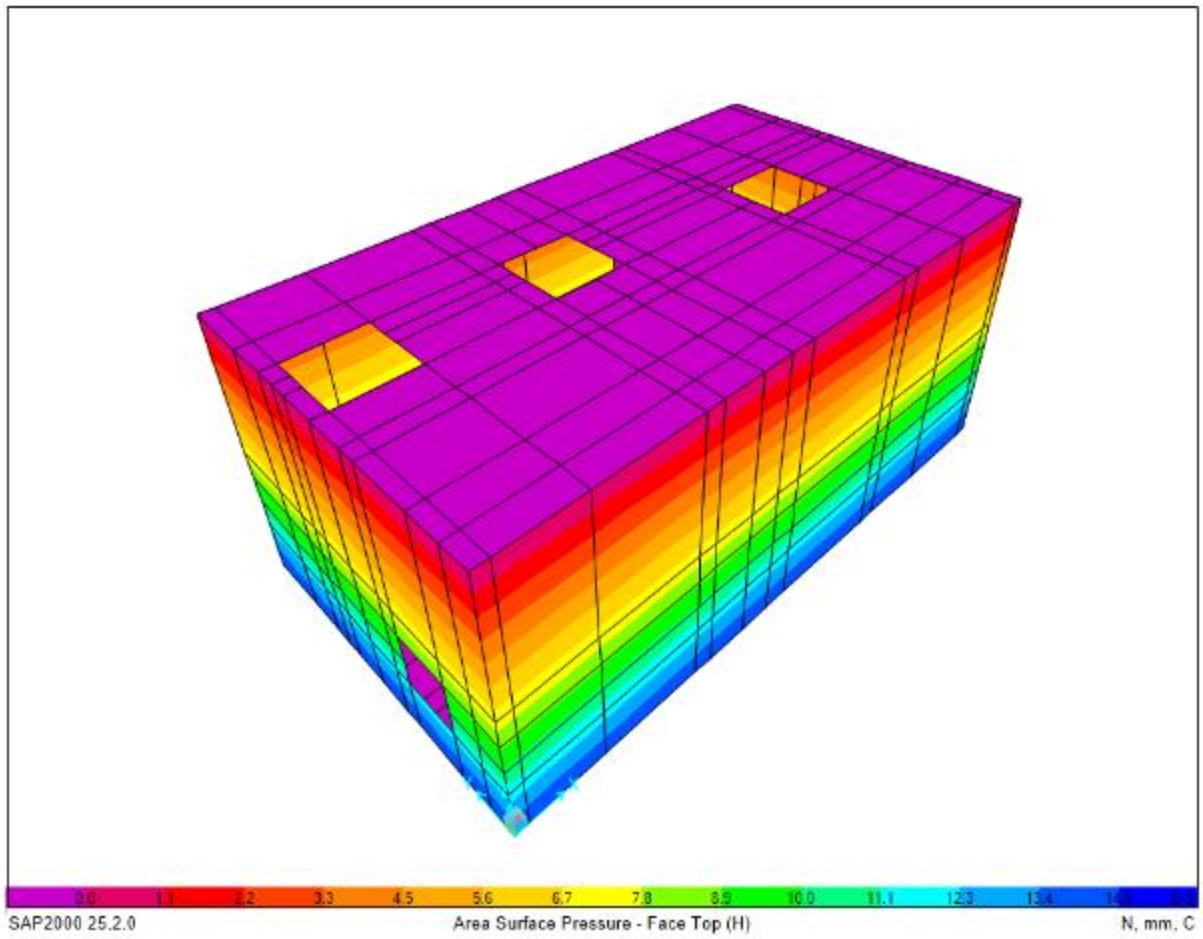

### 3.11.2 Acciones de cálculo en el modelo

**Peso propio**

El peso propio de los elementos (muros y losas de hormigón) SAP2000 lo introduce directamente con las definiciones que se han hecho de las propiedades de los elementos y los materiales. En el programa esta acción se denomina DEAD.



**Empuje del terreno**

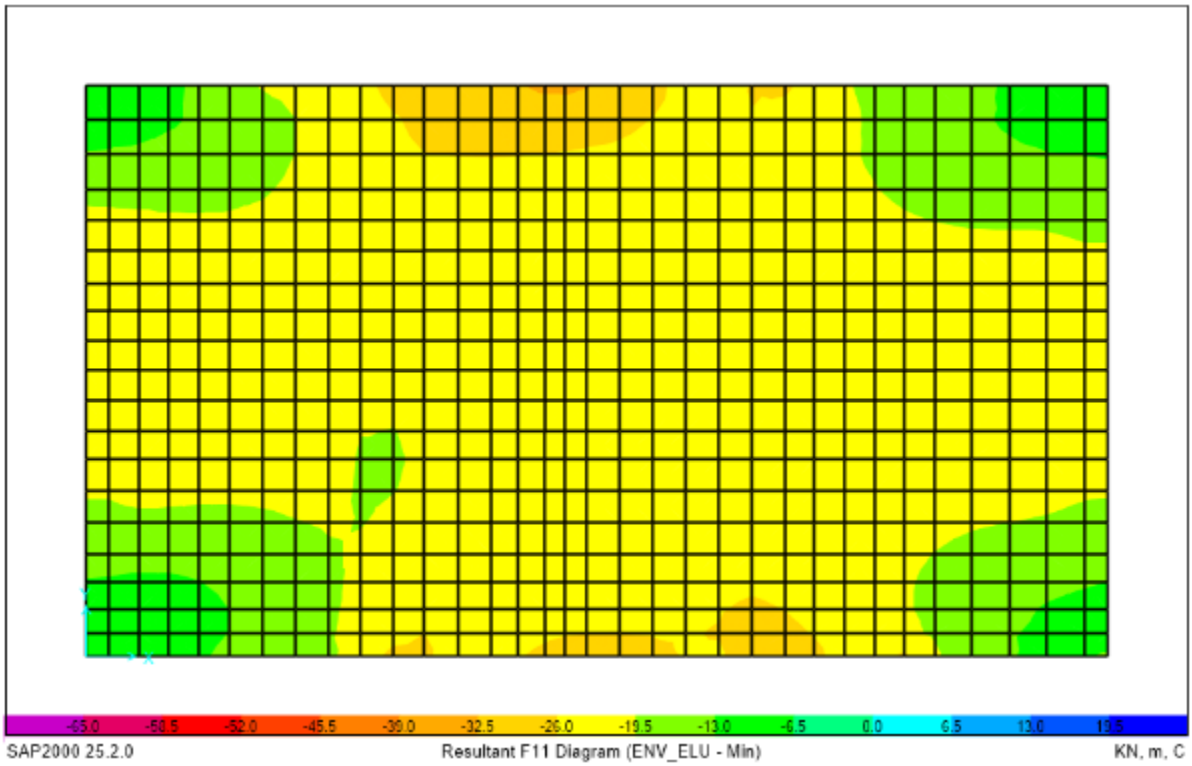


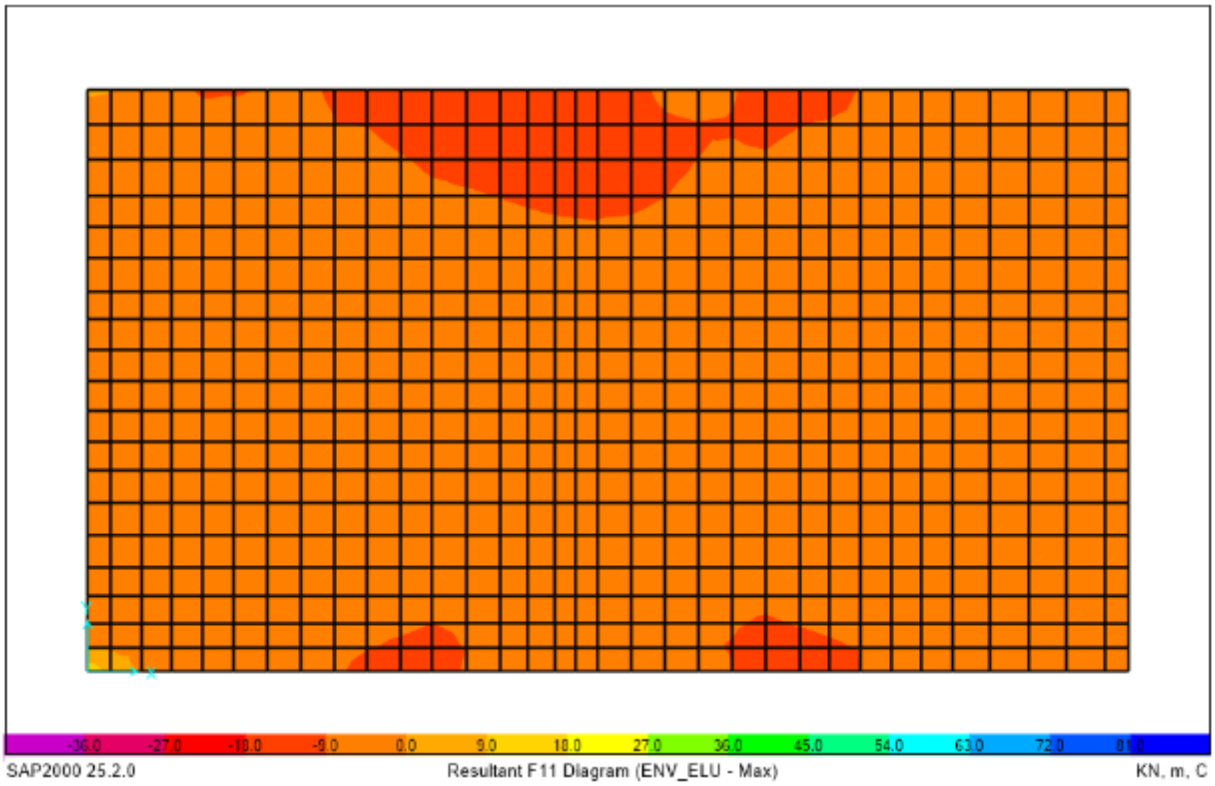

### 3.11.3 Resultados

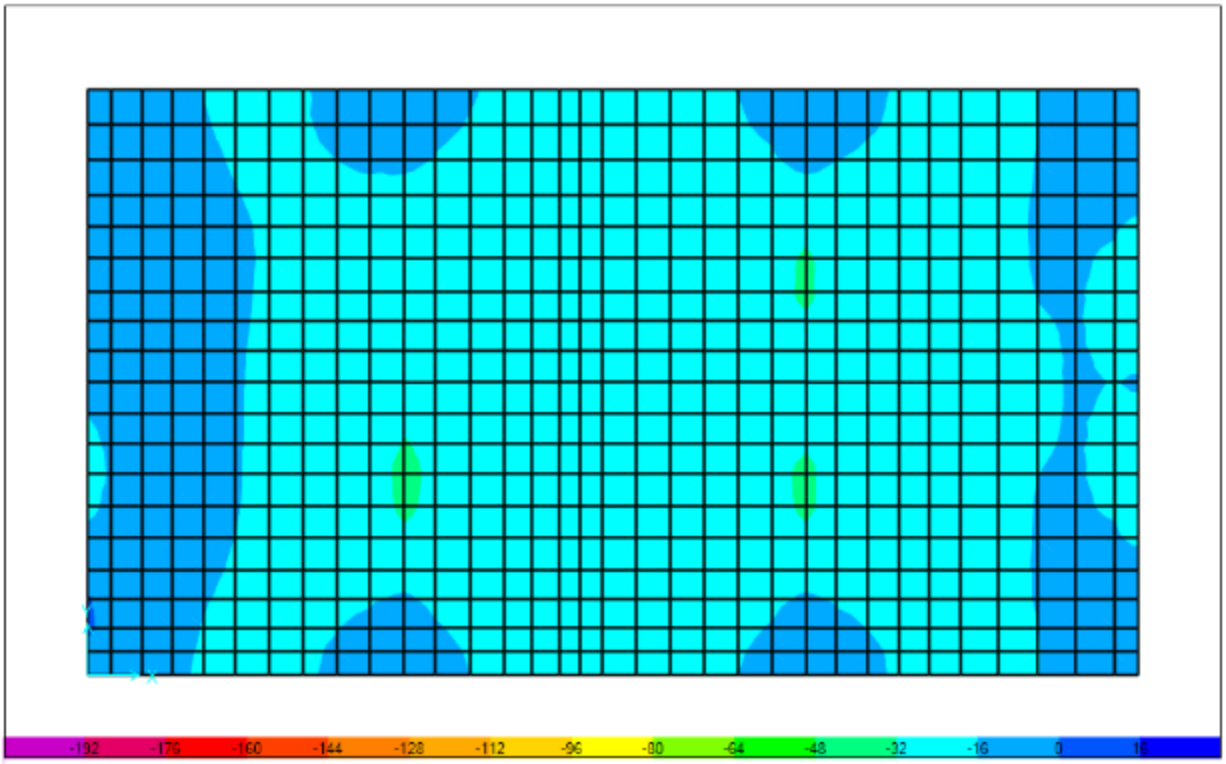
A continuación, se muestran los resultados del modelo para cada elemento estructural, diferenciando en losa inferior, muros, columnas y losa superior para todas las situaciones de diseño.

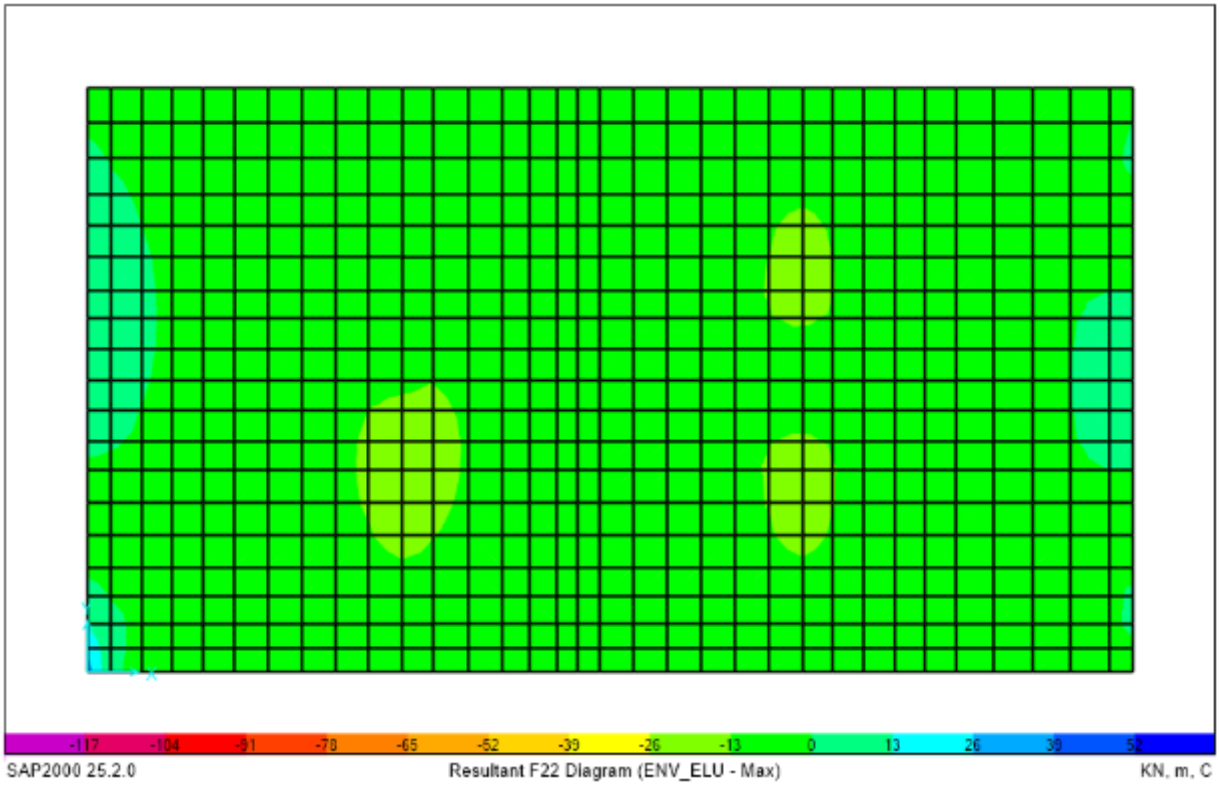
**Losa base inferior**

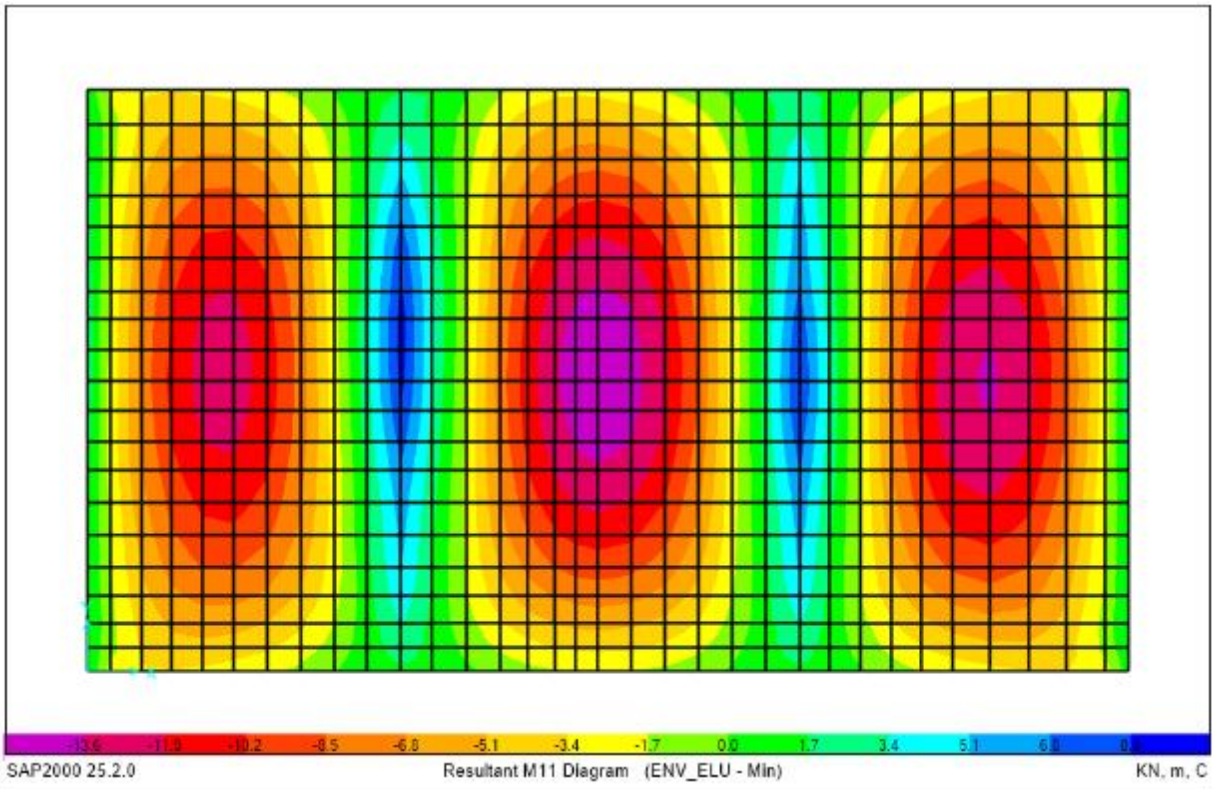
| LOSA BASE INFERIOR – ELU RESULTADOS | | | | | |
|---|---|---|---|---|---|
| | **$F_{11}$ (kN)** | **$M_{11}$ (kNm)** | **$F_{22}$ (kN)** | **$M_{22}$ (kNm)** | **$V_{max}$ (kN)** |
| **ELU (min)** | -34,32 | -14,88 | -36,08 | -13,83 | 0,31 |
| **ELU (max)** | 14,79 | 17,33 | 30,92 | 9,01 | 53,83 |

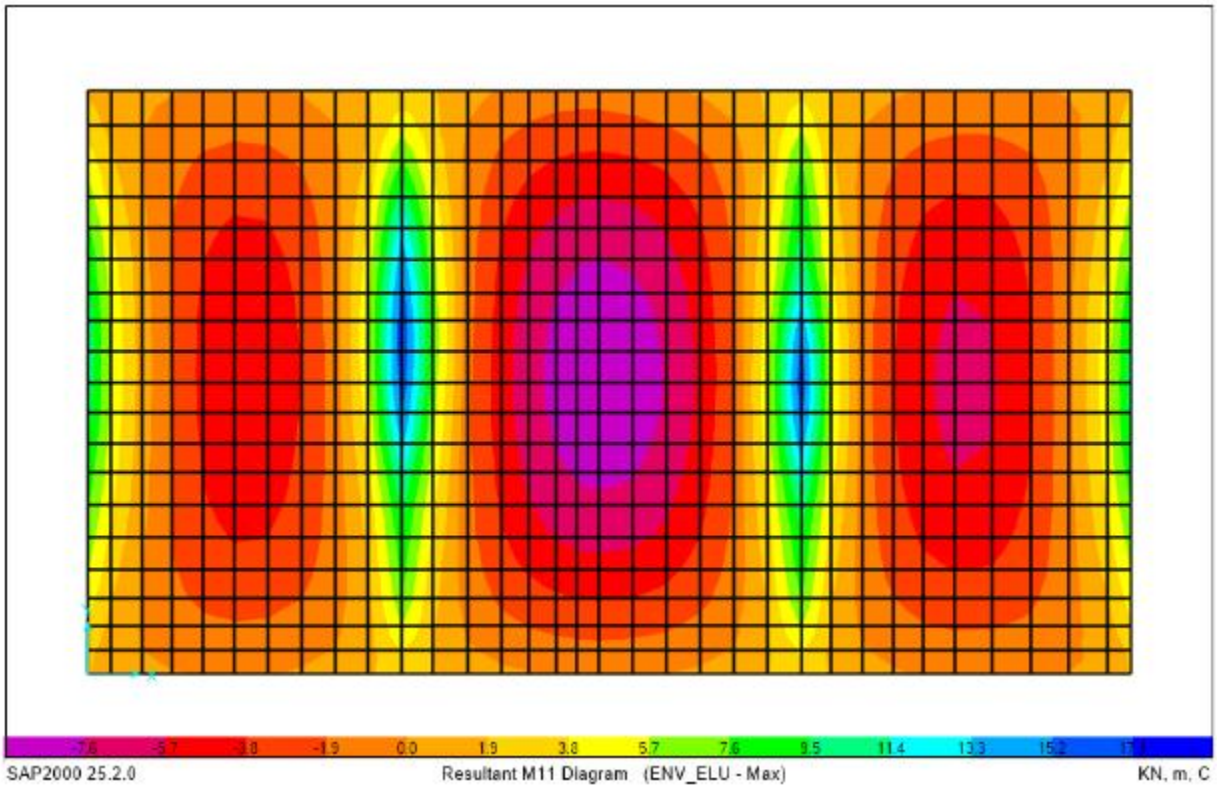

-65.0 -58.5 -52.0 -45.5 -39.0 -32.5 -26.0 -19.5 -13.0 -6.5 0.0 6.5 13.0 19.5
SAP2000 25.2.0
Resultant F11 Diagram (ENV_ELU - Min)
KN, m, C

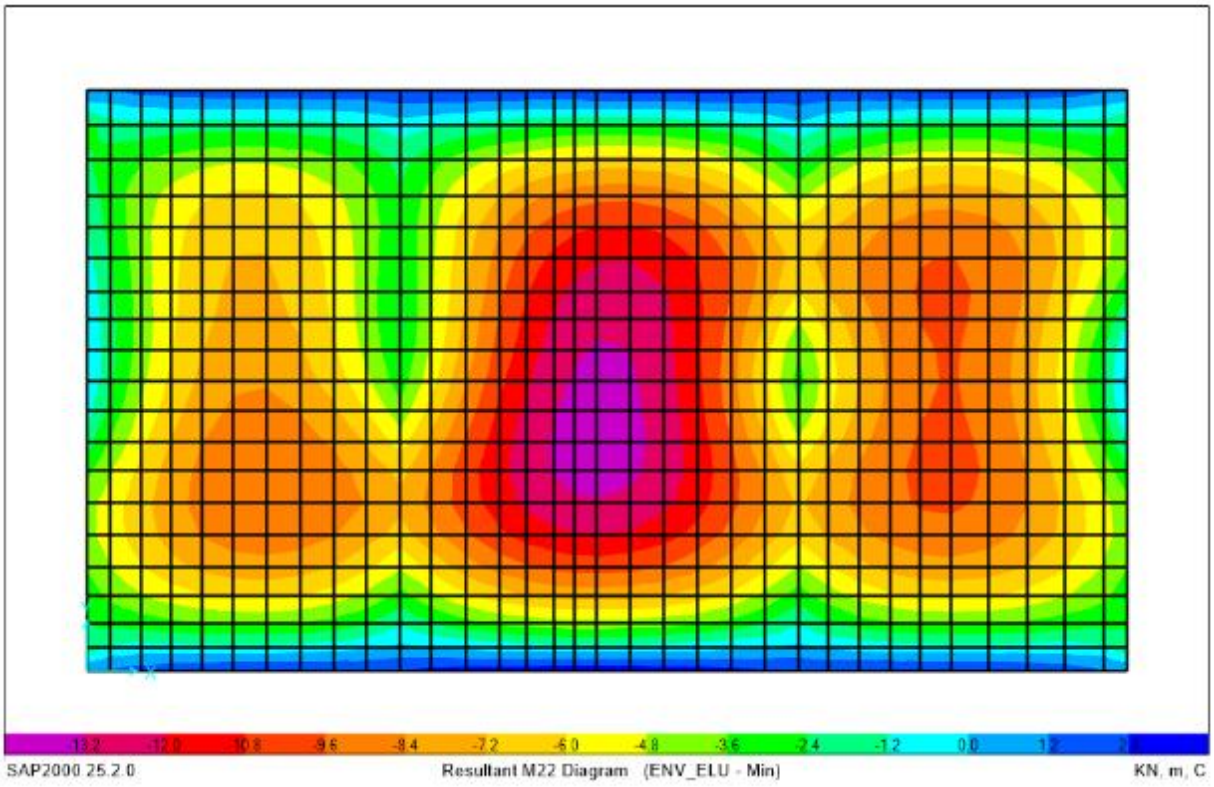

-36.0 -27.0 -18.0 -9.0 0.0 9.0 18.0 27.0 36.0 45.0 54.0 63.0 72.0 81.0
SAP2000 25.2.0
Resultant F11 Diagram (ENV_ELU - Max)
KN, m, C

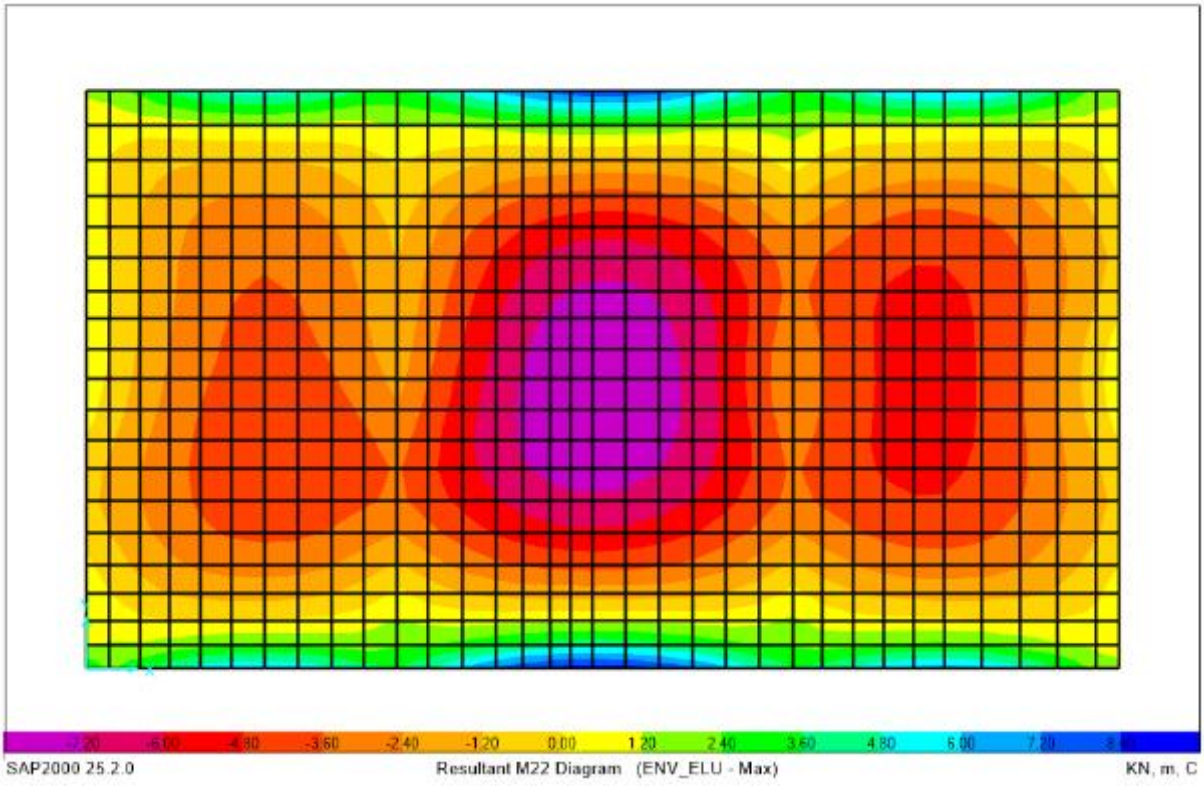

-192 -176 -160 -144 -128 -112 -96 -80 -64 -48 -32 -16 0 16
SAP2000 25.2.0
Resultant F22 Diagram (ENV_ELU - Min)
KN, m, C

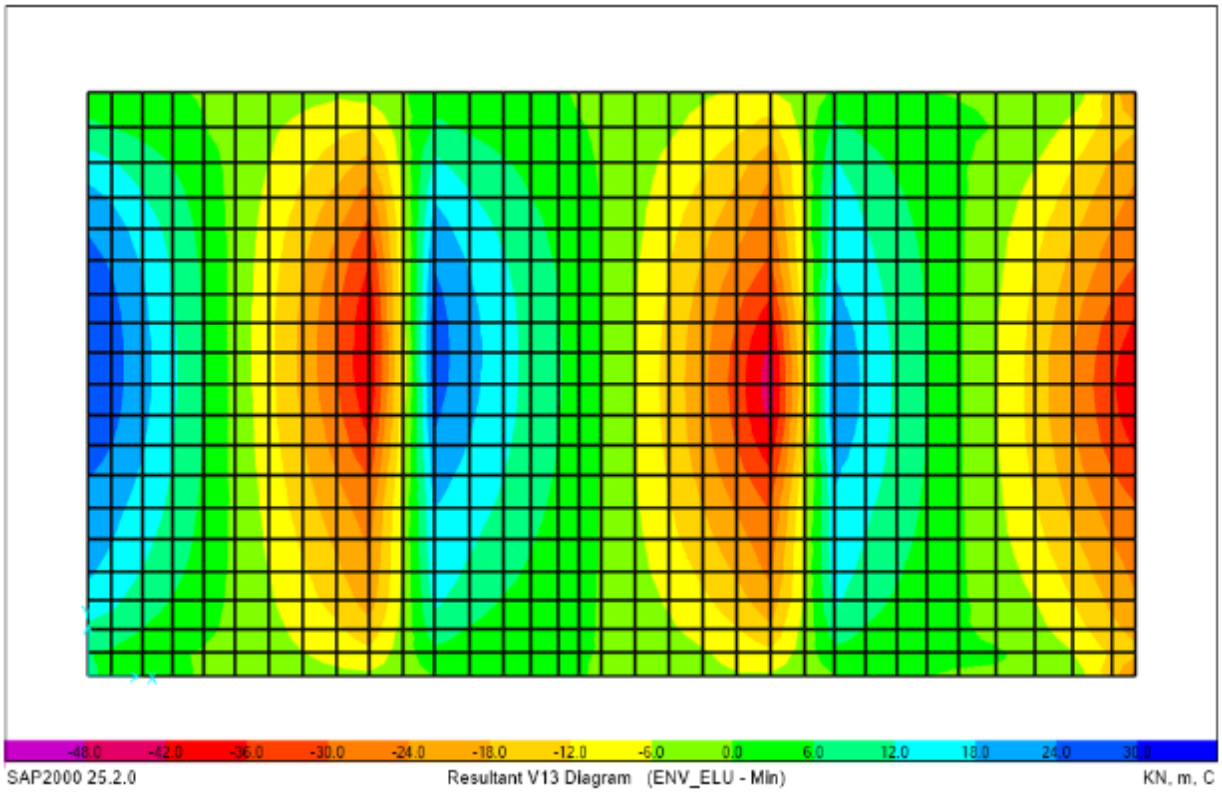

-117 -104 -91 -78 -65 -52 -39 -26 -13 0 13 26 39 52
SAP2000 25.2.0
Resultant F22 Diagram (ENV_ELU - Max)
KN, m, C

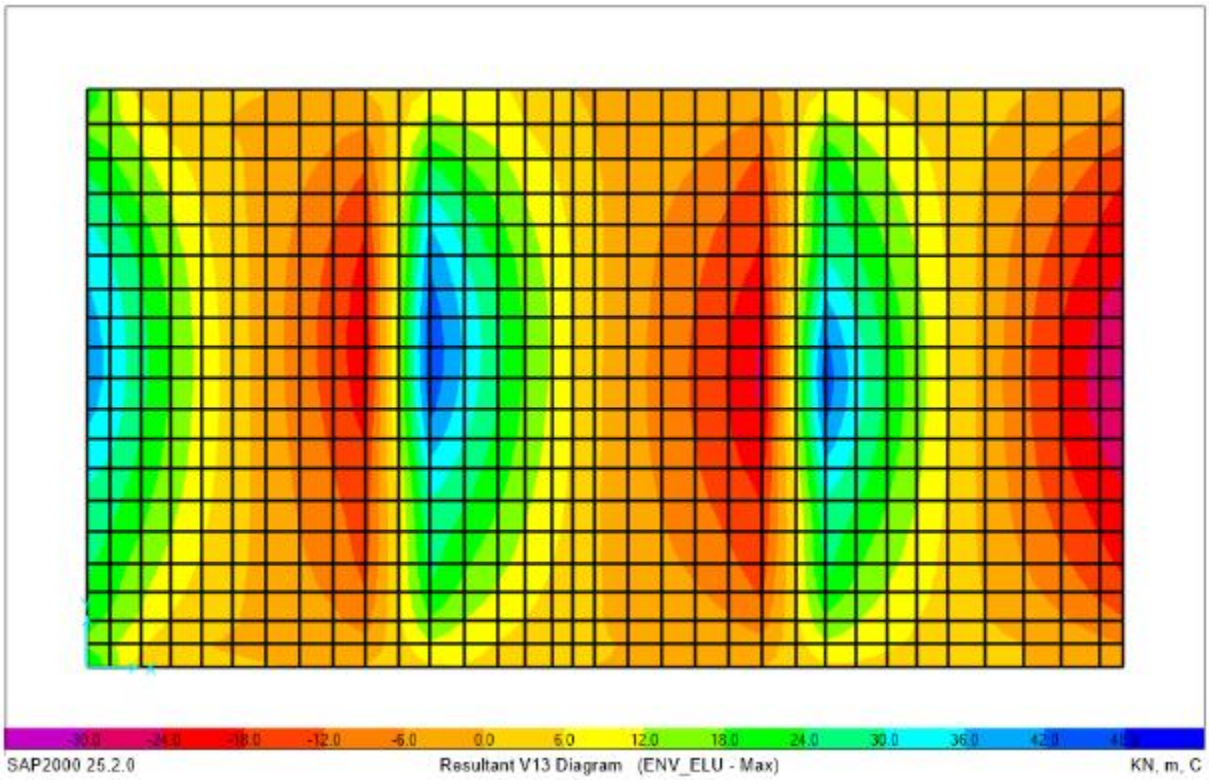

-13.6 -11.9 -10.2 -8.5 -6.8 -5.1 -3.4 -1.7 0.0 1.7 3.4 5.1 6.8 8.5
SAP2000 25.2.0
Resultant M11 Diagram (ENV_ELU - Min)
KN, m, C

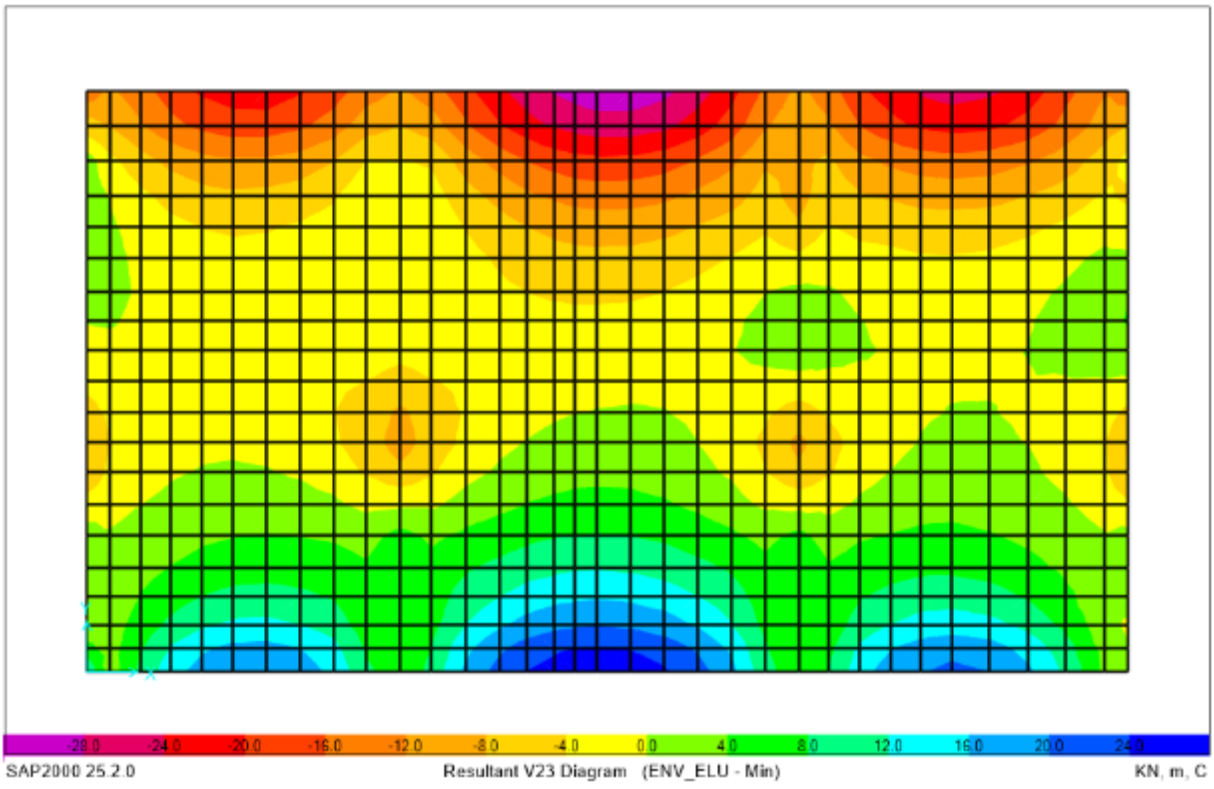

-7.6 -5.7 -3.8 -1.9 0.0 1.9 3.8 5.7 7.6 9.5 11.4 13.3 15.2 17.1
SAP2000 25.2.0
Resultant M11 Diagram (ENV_ELU - Max)
KN, m, C

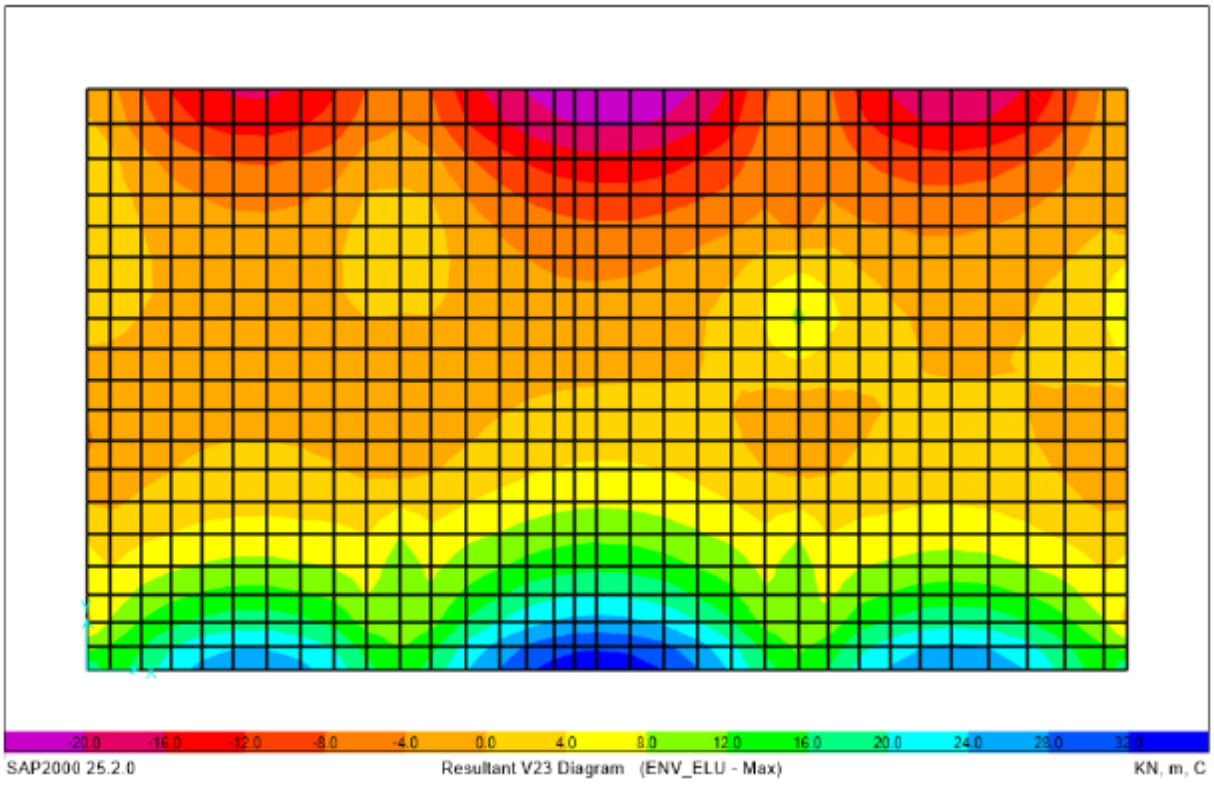

-13.2 -12.0 -10.8 -9.6 -8.4 -7.2 -6.0 -4.8 -3.6 -2.4 -1.2 0.0 1.2
SAP2000 25.2.0
Resultant M22 Diagram (ENV_ELU - Min)
KN, m, C


-7.20 -6.00 -4.80 -3.60 -2.40 -1.20 0.00 1.20 2.40 3.60 4.80 6.00 7.20
SAP2000 25.2.0
Resultant M22 Diagram (ENV_ELU - Max)
KN, m, C


-48.0 -42.0 -36.0 -30.0 -24.0 -18.0 -12.0 -6.0 0.0 6.0 12.0 18.0 24.0 30.0
SAP2000 25.2.0
Resultant V13 Diagram (ENV_ELU - Min)
KN, m, C

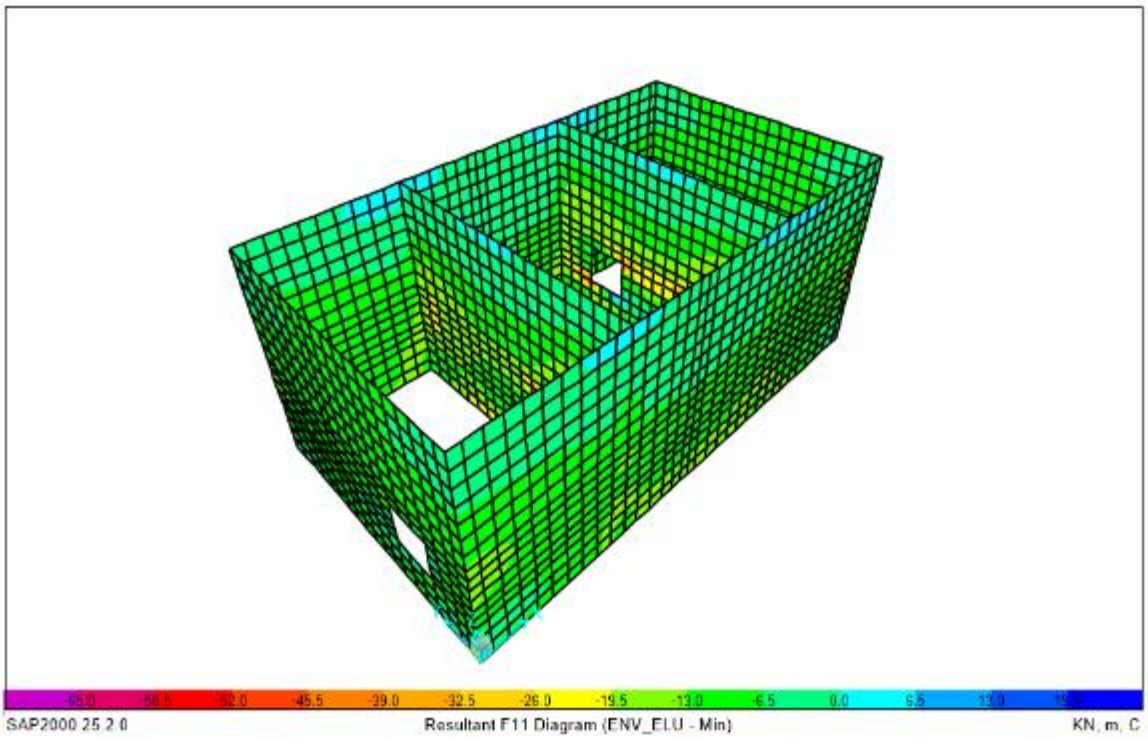

-30.0 -24.0 -18.0 -12.0 -6.0 0.0 6.0 12.0 18.0 24.0 30.0 36.0 42.0 48.0
SAP2000 25.2.0
Resultant V13 Diagram (ENV_ELU - Max)
KN, m, C

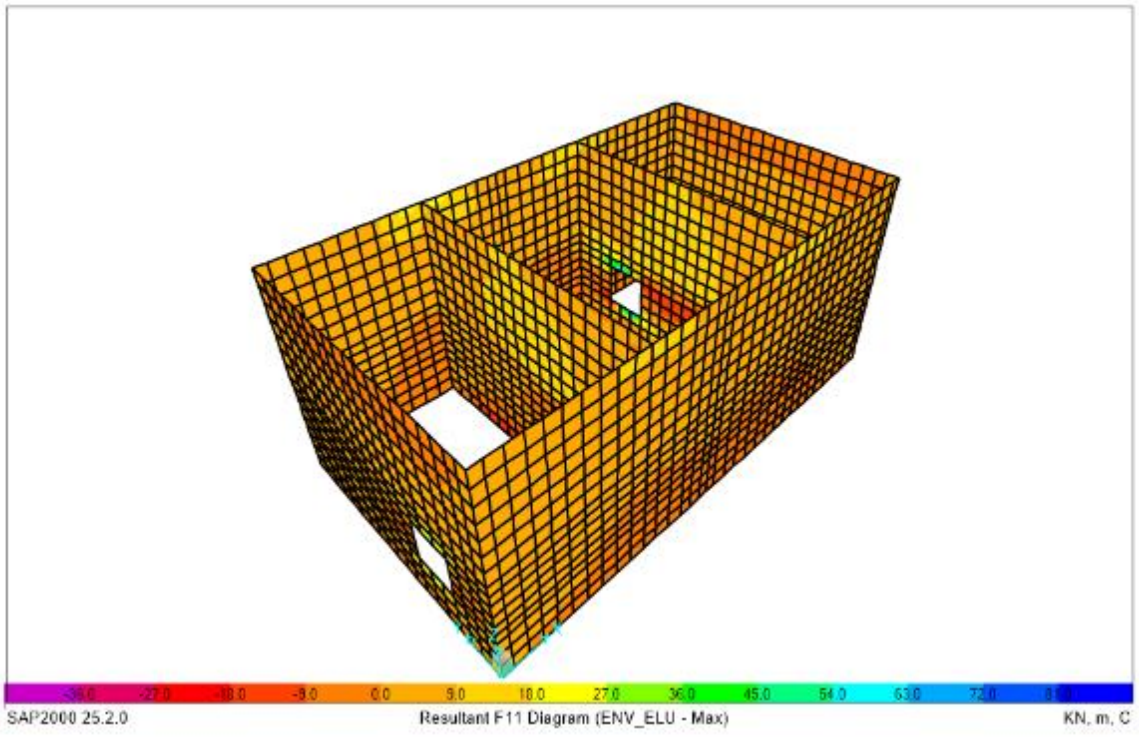

-28.0 -24.0 -20.0 -16.0 -12.0 -8.0 -4.0 0.0 4.0 8.0 12.0 16.0 20.0 24.0
SAP2000 25.2.0
Resultant V23 Diagram (ENV_ELU - Min)
KN, m, C

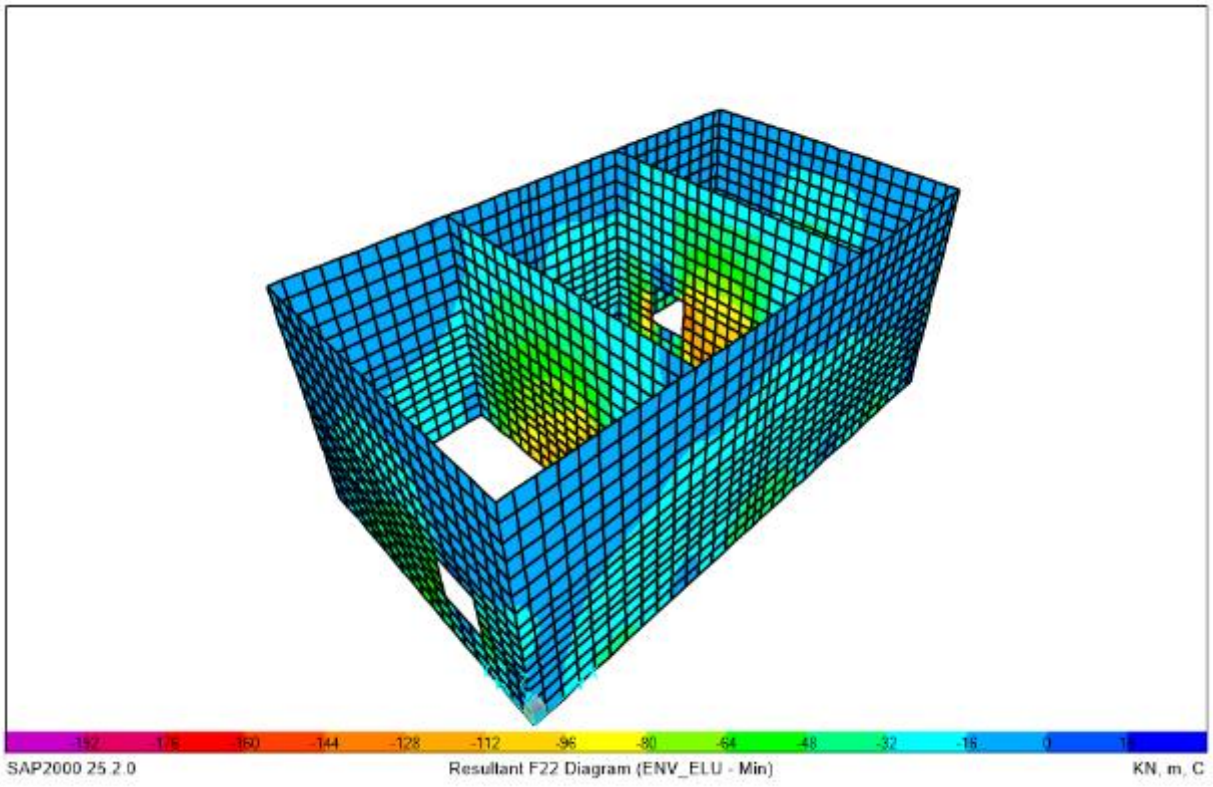

-20.0 -16.0 -12.0 -8.0 -4.0 0.0 4.0 8.0 12.0 16.0 20.0 24.0 28.0 32.0
SAP2000 25.2.0
Resultant V23 Diagram (ENV_ELU - Max)
KN, m, C

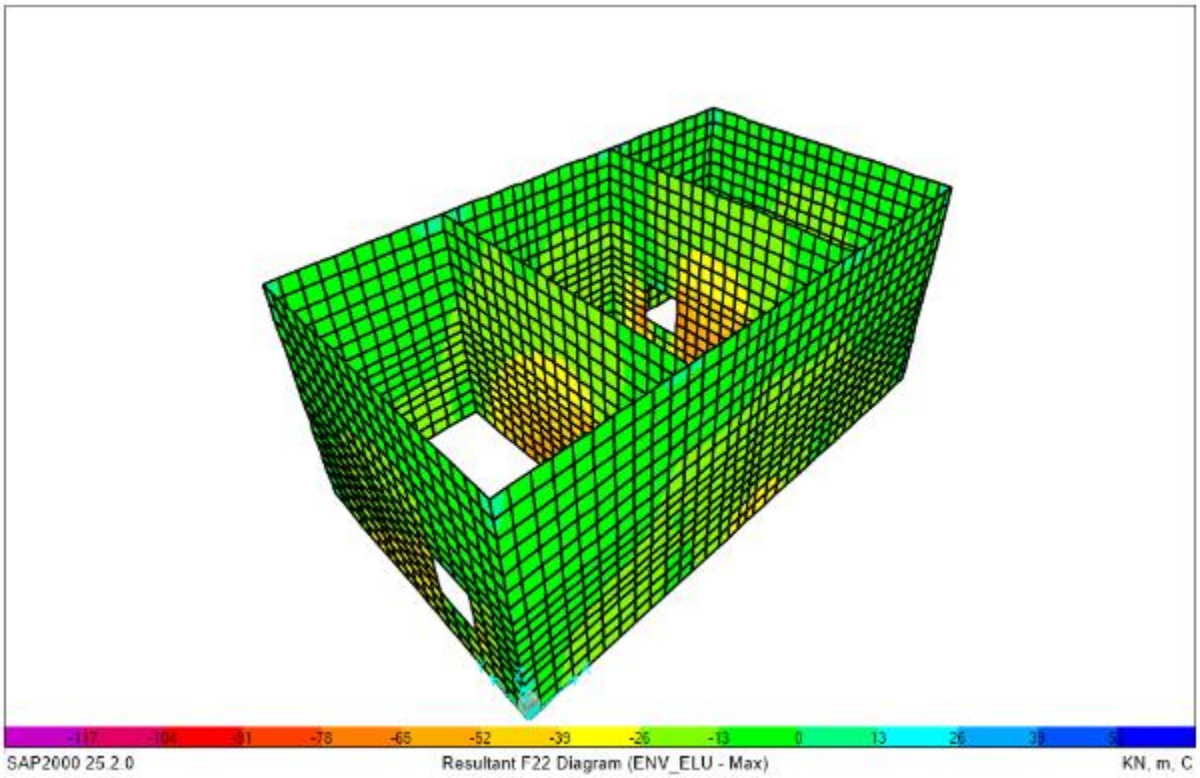
**Muros**

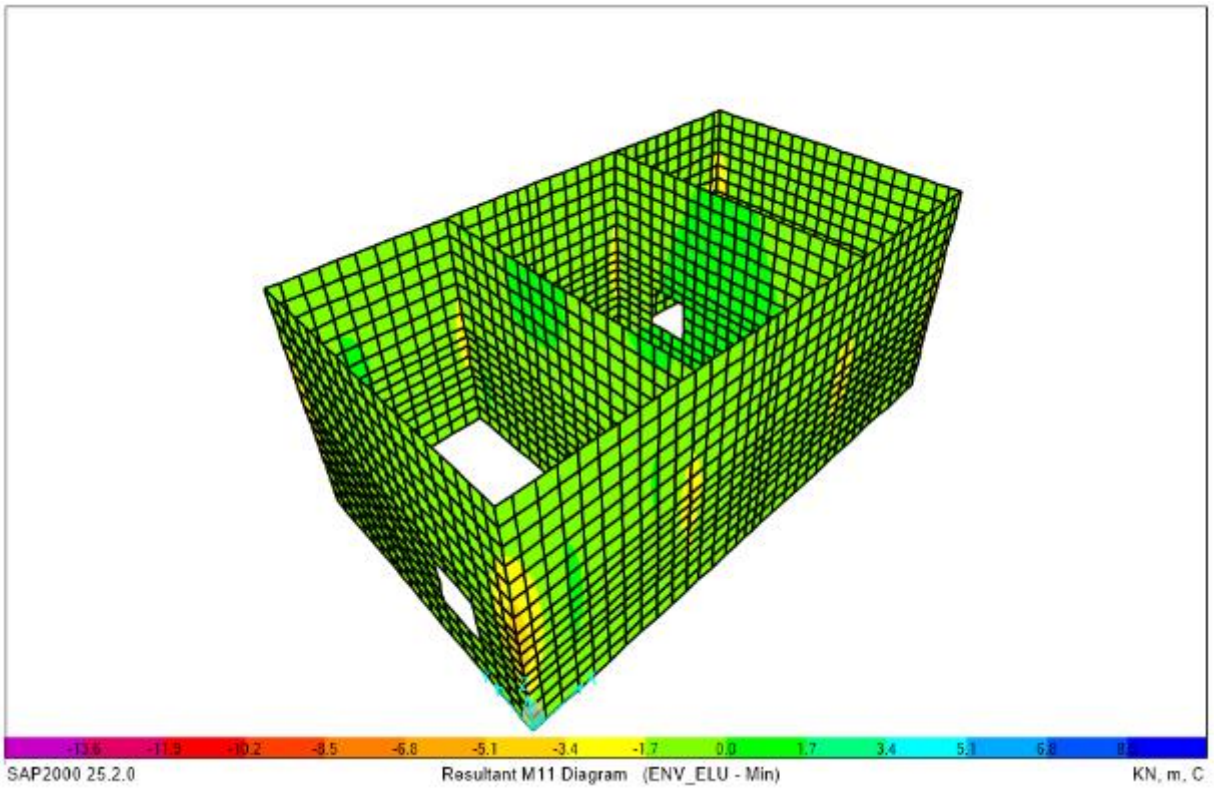
| MUROS – LRFD RESULTADOS | | | | | |
|---|---|---|---|---|---|
| | **$F_{11}$ (kN)** | **$M_{11}$ (kNm)** | **$F_{22}$ (kN)** | **$M_{22}$ (kNm)** | **Vmax (kN)** |
| **ELU (min)** | -66,95 | -4,95 | -206,36 | -10,46 | 0,1 |
| **ELU (max)** | 89,24 | 3,75 | 50,14 | 6,4 | 29,78 |

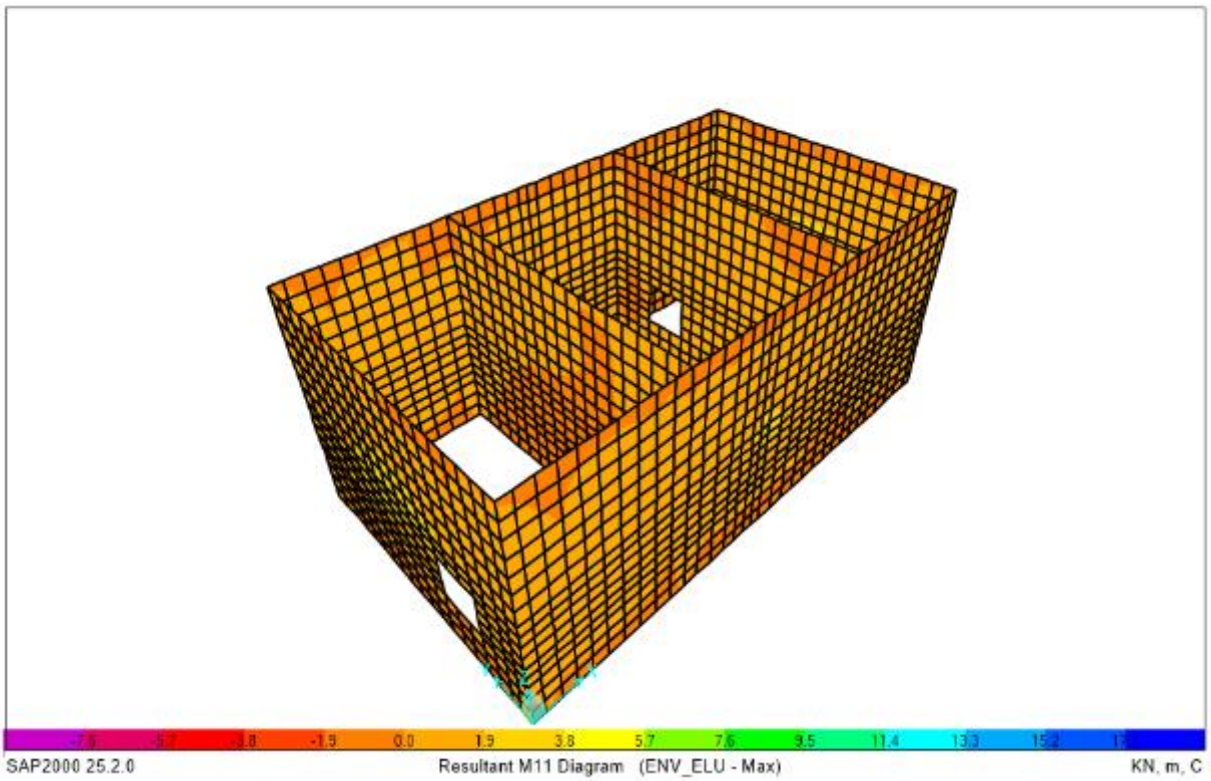


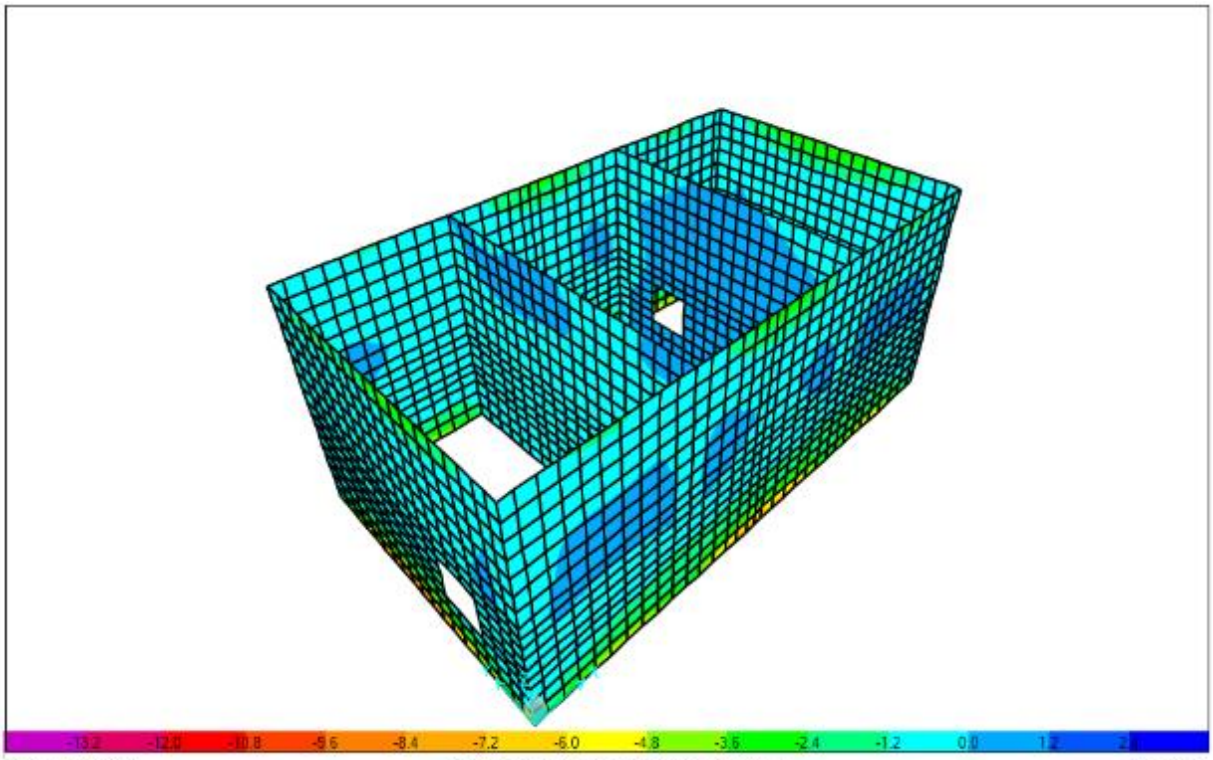



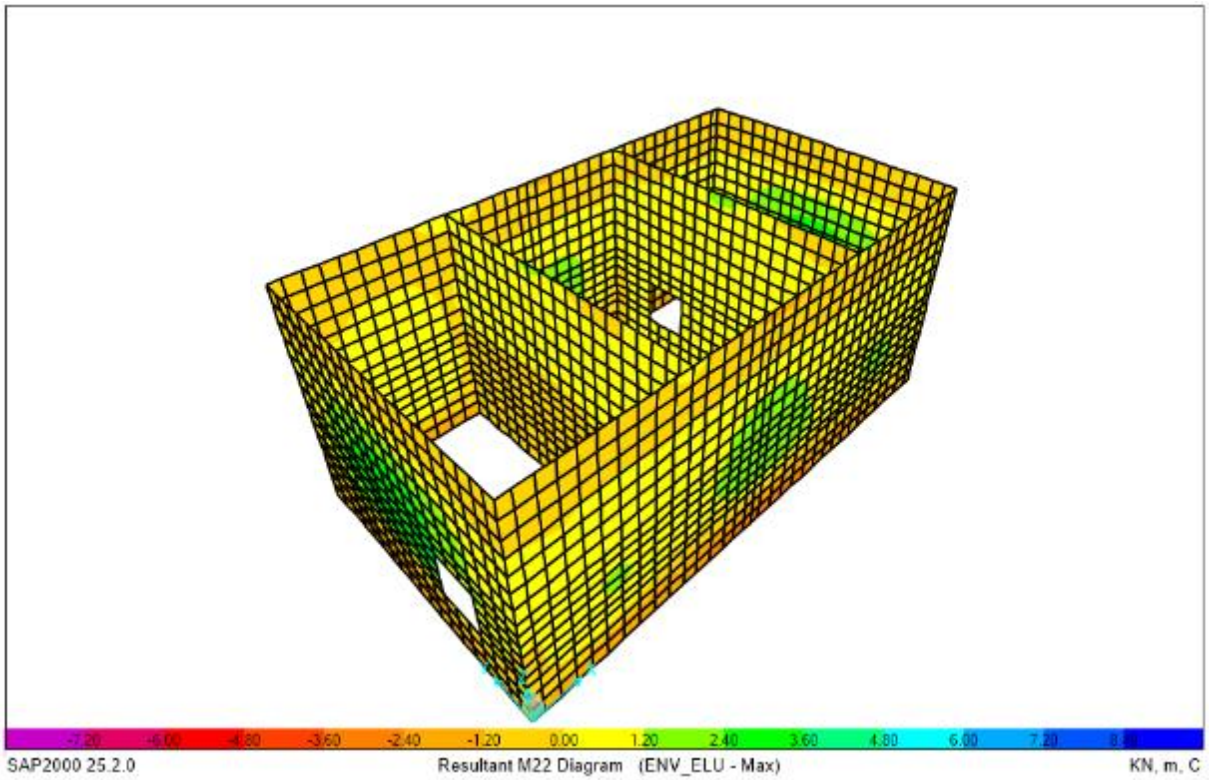

-192
-176
-160
-144
-128
-112
-96
-80
-64
-48
-32
-16
0
16
SAP2000 25.2.0
Resultant F22 Diagram (ENV_ELU - Min)
KN, m, C

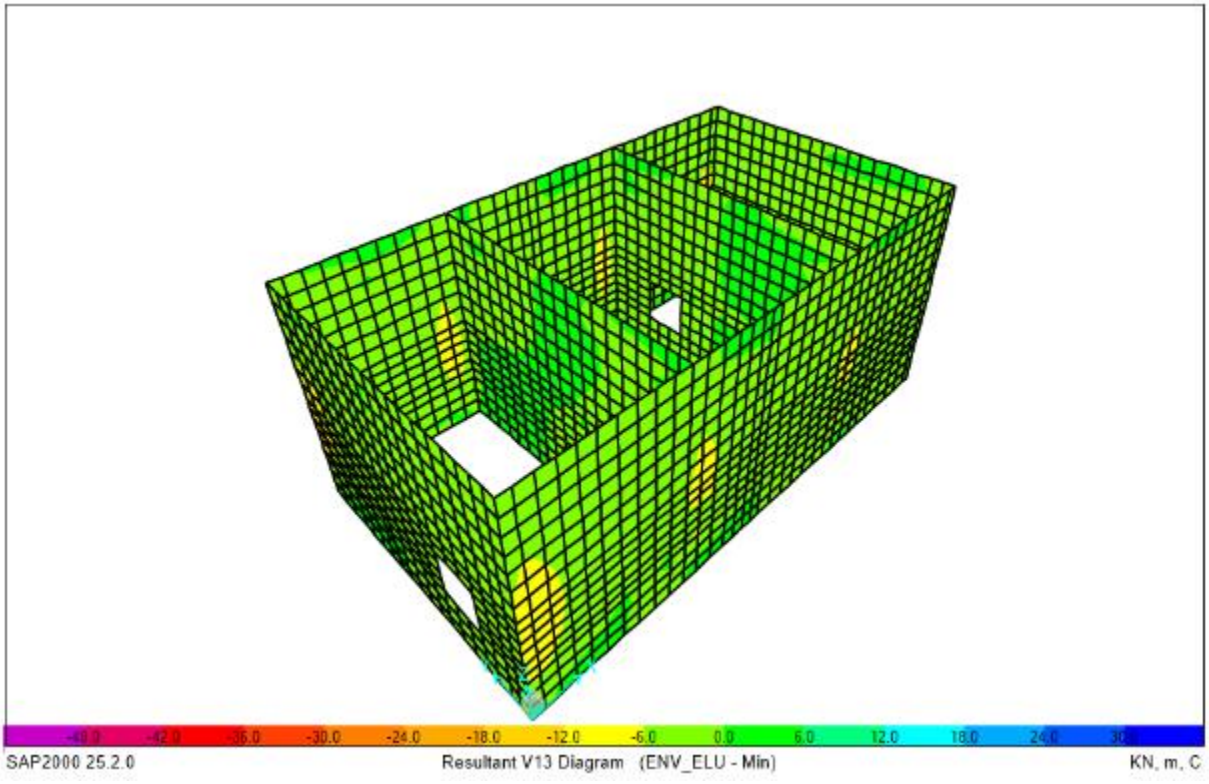

-117
-104
-91
-78
-65
-52
-39
-26
-13
0
13
26
39
52
SAP2000 25.2.0
Resultant F22 Diagram (ENV_ELU - Max)
KN, m, C

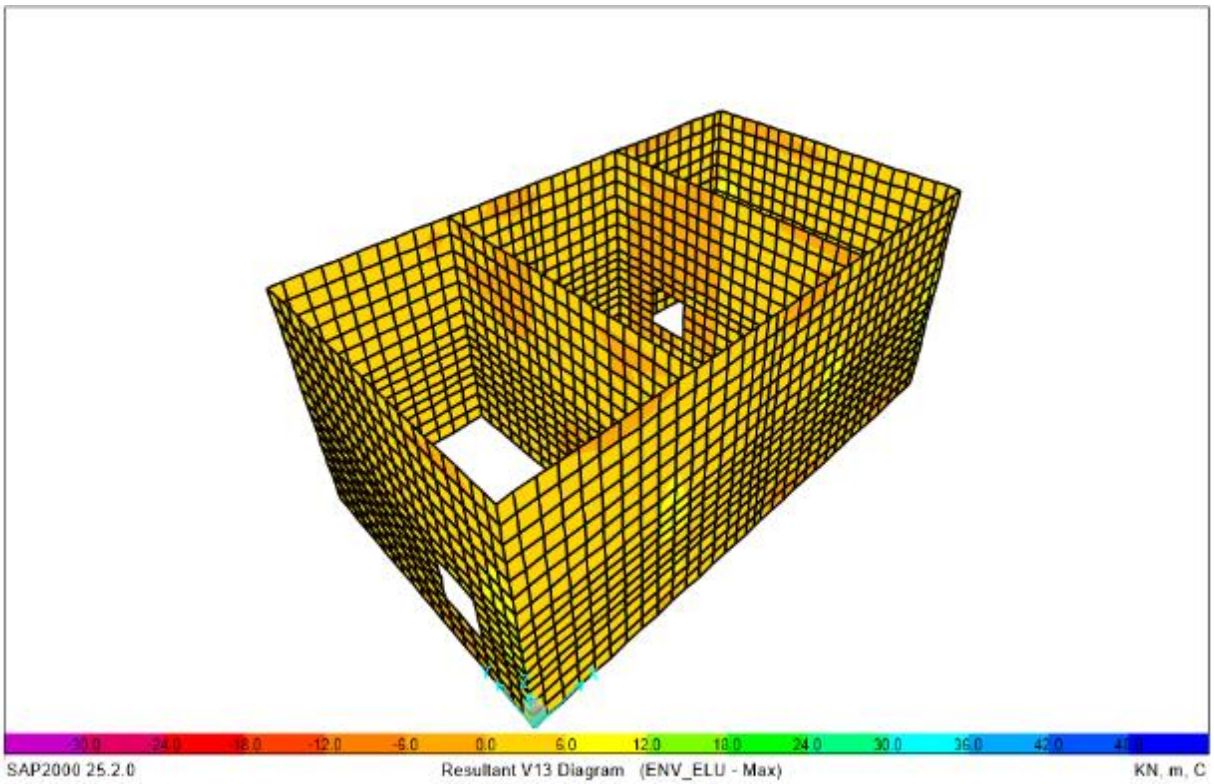

-13.6 -11.9 -10.2 -8.5 -6.8 -5.1 -3.4 -1.7 0.0 1.7 3.4 5.1 6.8
SAP2000 25.2.0
Resultant M11 Diagram (ENV_ELU - Min)
KN, m, C

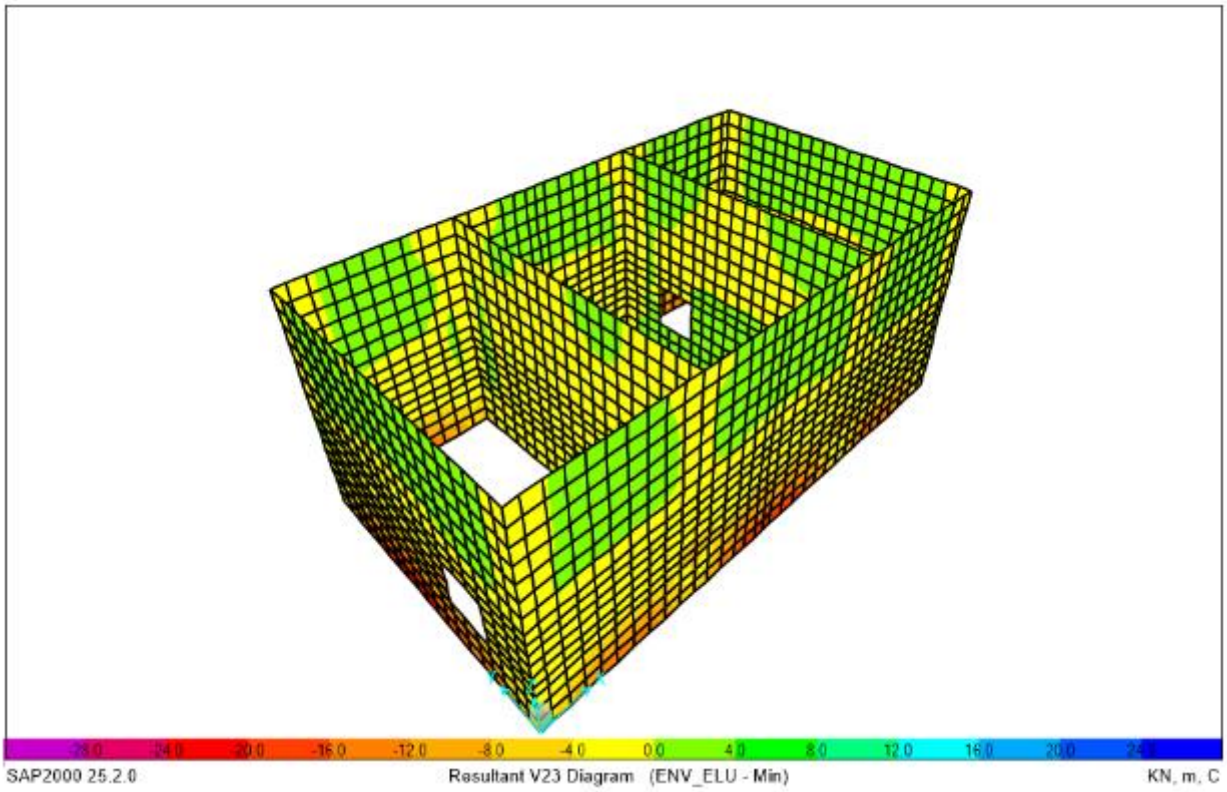

-7.6 -5.7 -3.8 -1.9 0.0 1.9 3.8 5.7 7.6 9.5 11.4 13.3 15.2
SAP2000 25.2.0
Resultant M11 Diagram (ENV_ELU - Max)
KN, m, C

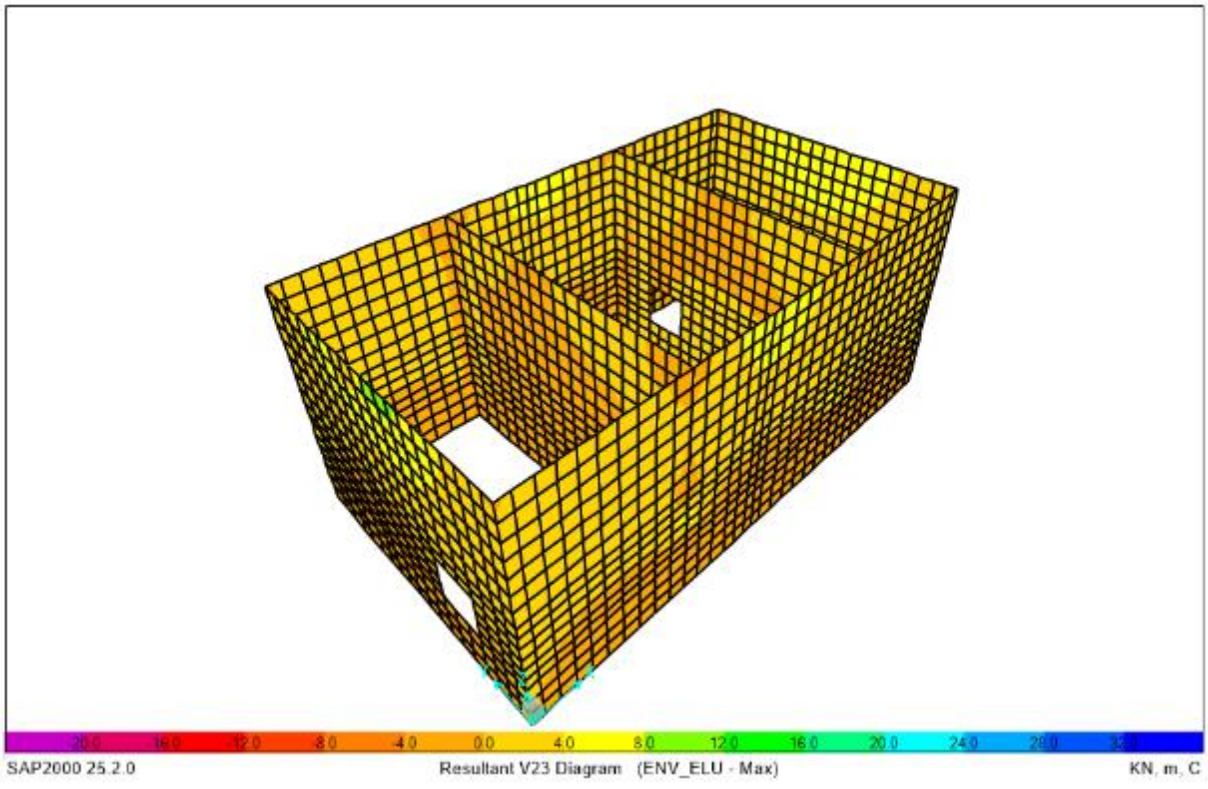

-13.2
-12.0
-10.8
-9.6
-8.4
-7.2
-6.0
-4.8
-3.6
-2.4
-1.2
0.0
SAP2000 25.2.0
Resultant M22 Diagram (ENV_ELU - Min)
KN, m, C


-7.20
-6.00
-4.80
-3.60
-2.40
-1.20
0.00
1.20
2.40
3.60
4.80
6.00
7.20
SAP2000 25.2.0
Resultant M22 Diagram (ENV_ELU - Max)
KN, m, C


-48.0 -42.0 -36.0 -30.0 -24.0 -18.0 -12.0 -6.0 0.0 6.0 12.0 18.0 24.0 30.0
SAP2000 25.2.0
Resultant V13 Diagram (ENV_ELU - Min)
KN, m, C

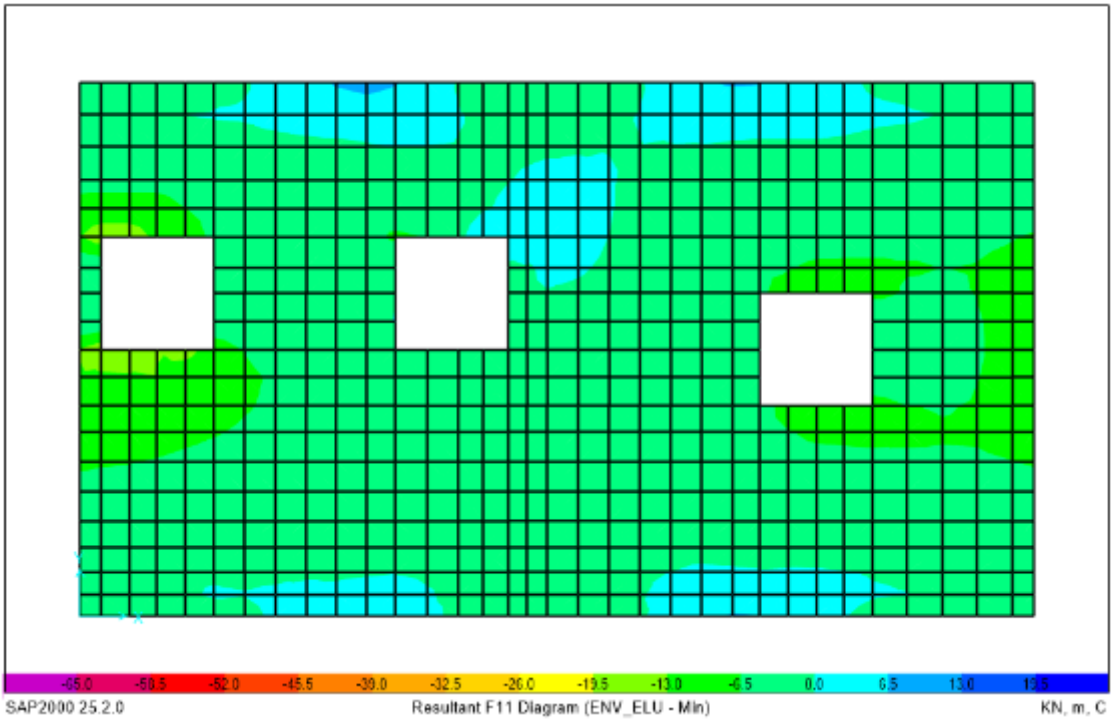

-30.0 -24.0 -18.0 -12.0 -6.0 0.0 6.0 12.0 18.0 24.0 30.0 36.0 42.0 48.0
SAP2000 25.2.0
Resultant V13 Diagram (ENV_ELU - Max)
KN, m, C

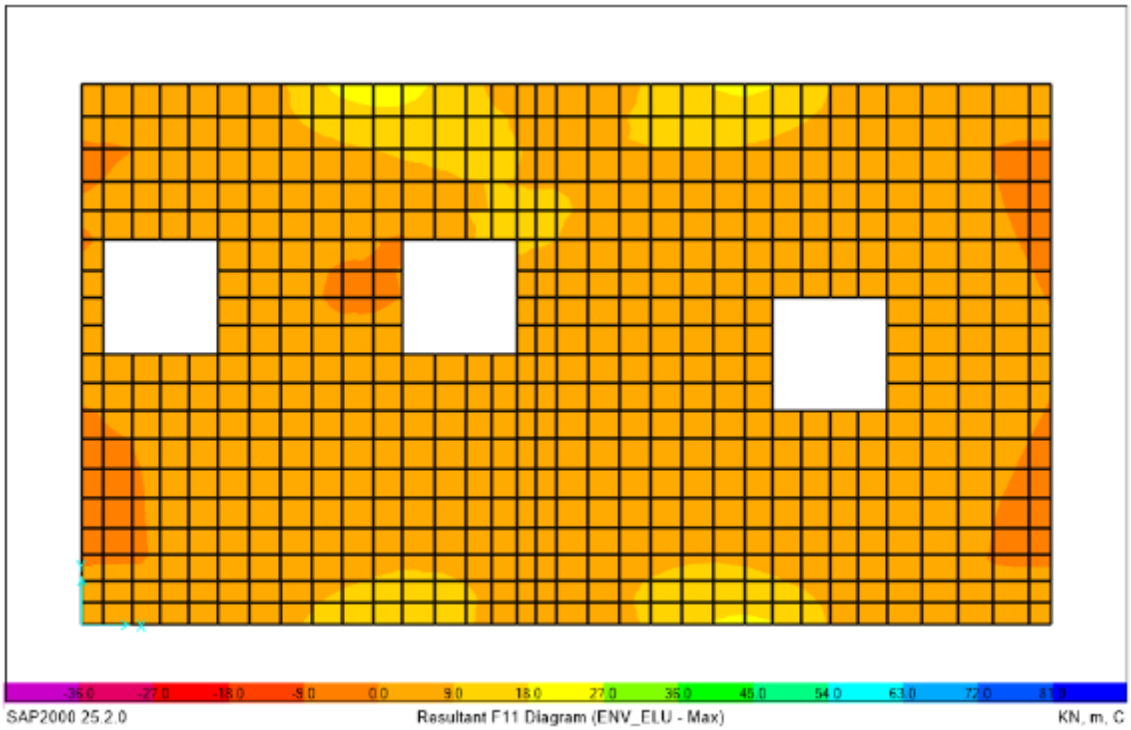

-28.0 -24.0 -20.0 -16.0 -12.0 -8.0 -4.0 0.0 4.0 8.0 12.0 16.0 20.0 24.0
SAP2000 25.2.0
Resultant V23 Diagram (ENV_ELU - Min)
KN, m, C

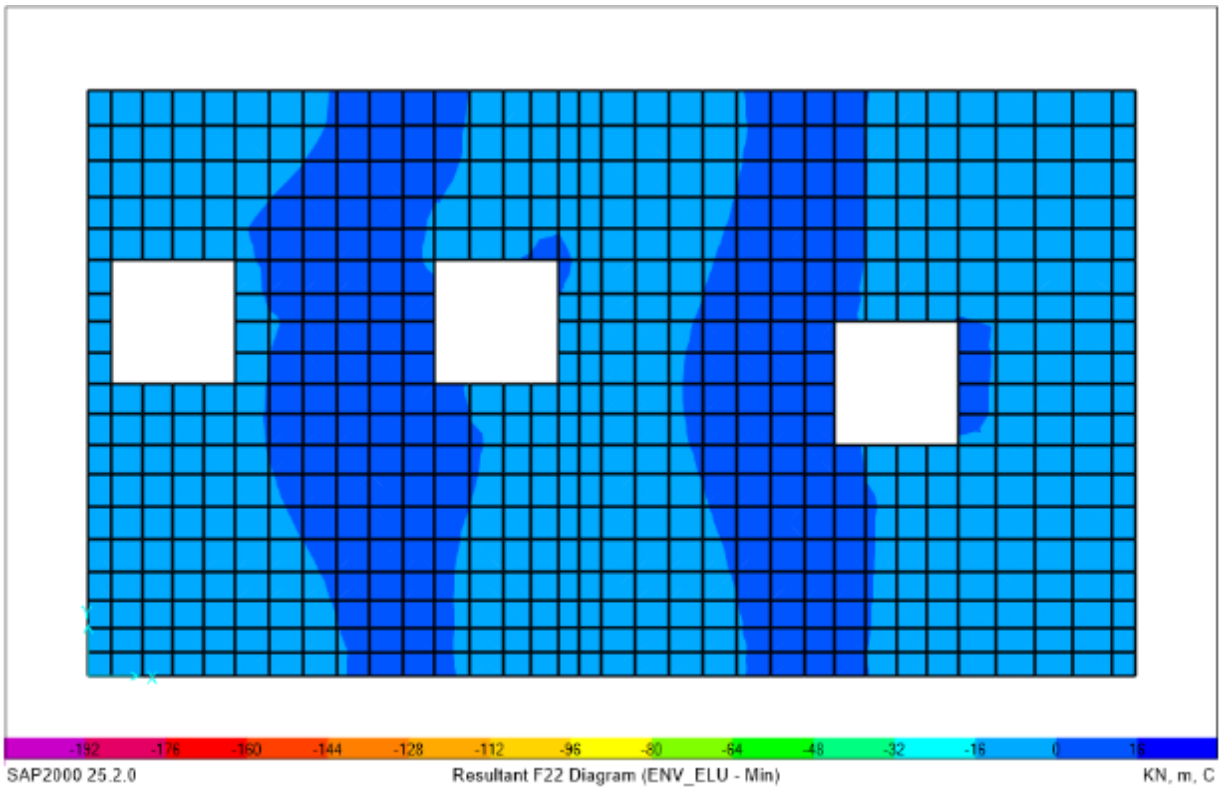

-20.0 -16.0 -12.0 -8.0 -4.0 0.0 4.0 8.0 12.0 16.0 20.0 24.0 28.0
SAP2000 25.2.0
Resultant V23 Diagram (ENV_ELU - Max)
KN, m, C

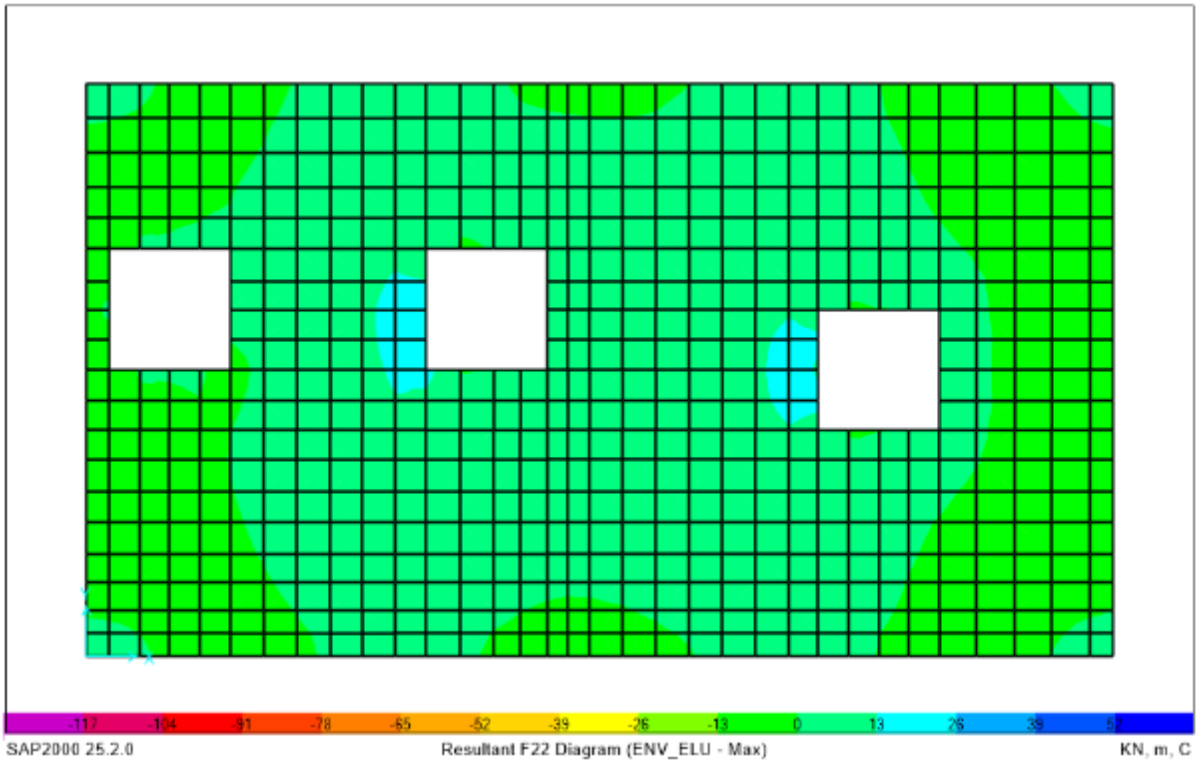
**Losa superior**

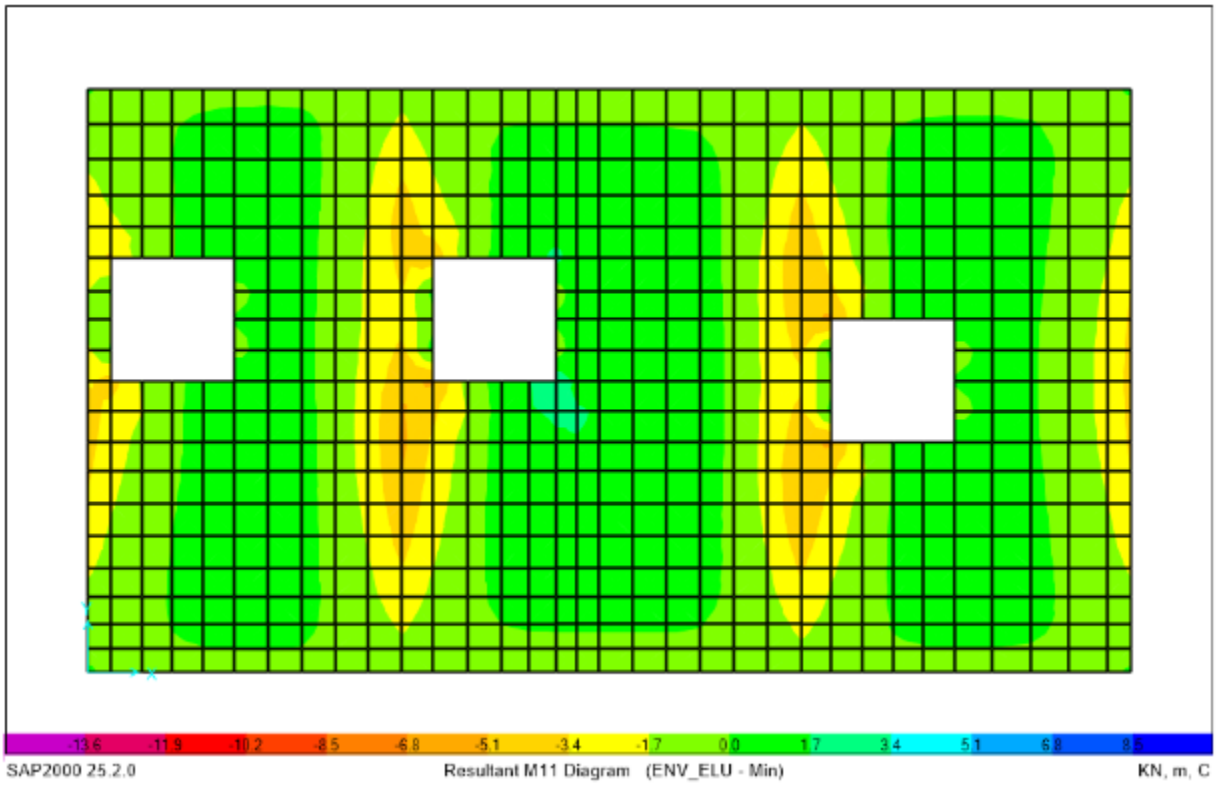
| LOSA SUPERIOR - LRFD RESULTADOS | | | | | |
|---|---|---|---|---|---|
| | **$F_{11}$ (kN)** | **$M_{11}$ (kNm)** | **$F_{22}$ (kN)** | **$M_{22}$ (kNm)** | **Vmax (kN)** |
| **ELU (min)** | -23,71 | -8,43 | -14,27 | -3,43 | 0,04 |
| **ELU (max)** | 27,7 | 6,48 | 25,15 | 2,36 | 34,53 |

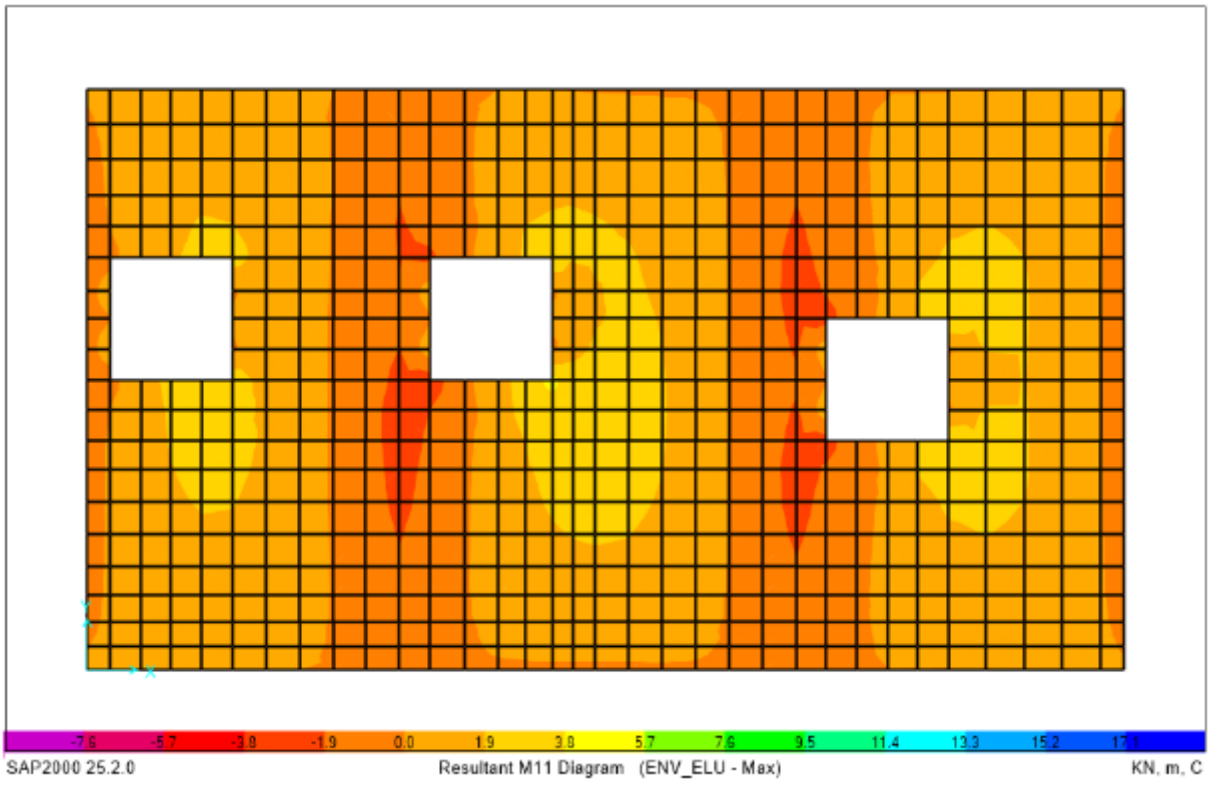


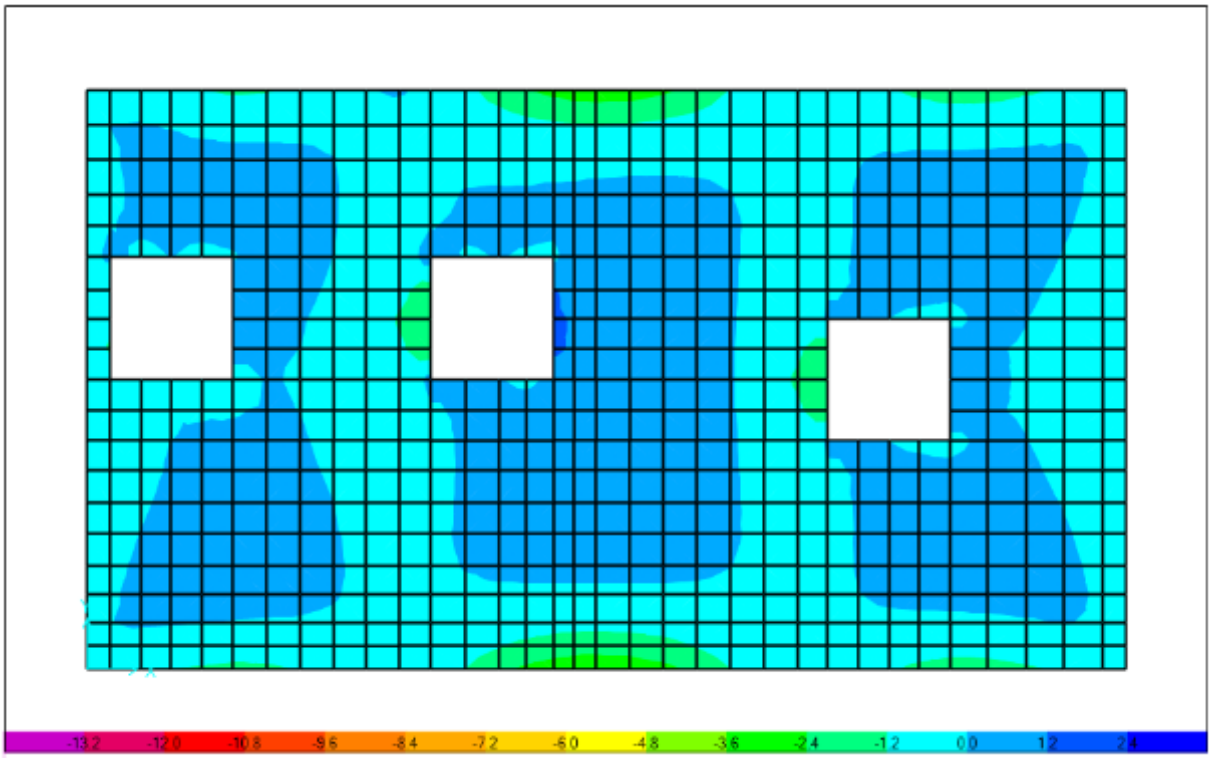



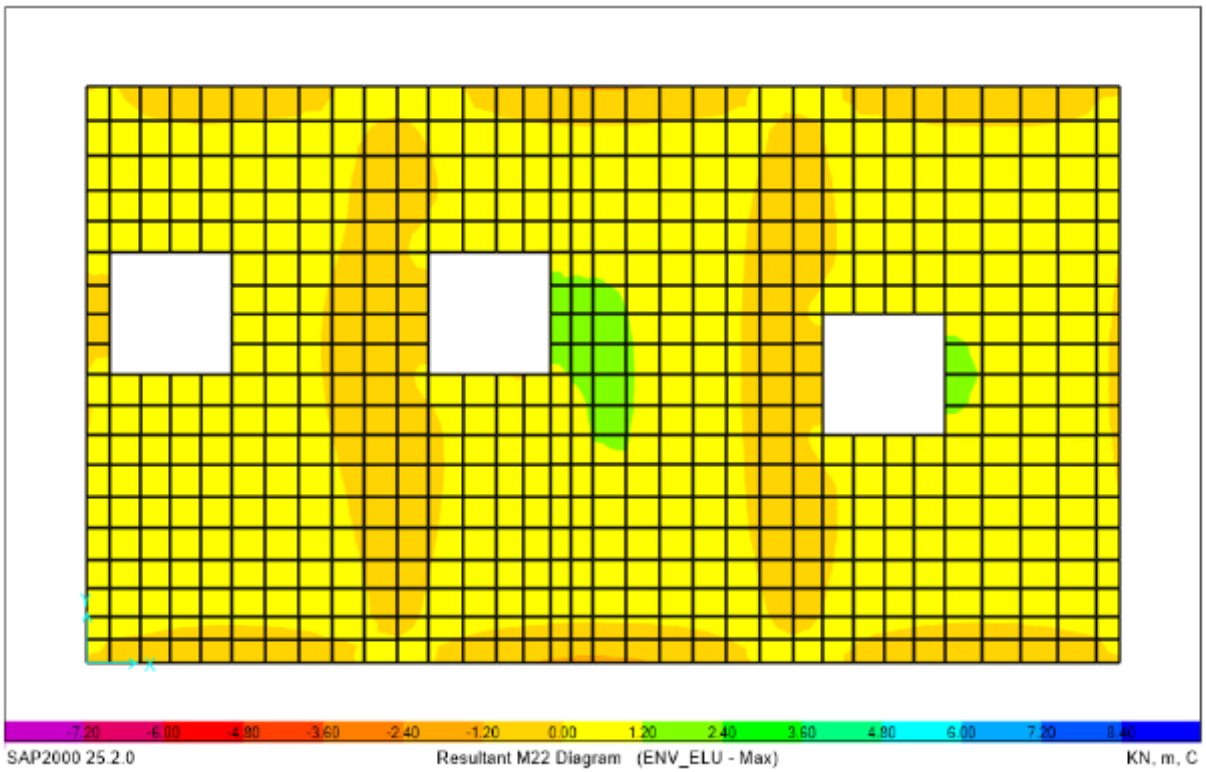

-192 -176 -160 -144 -128 -112 -96 -80 -64 -48 -32 -16 0 16
SAP2000 25.2.0
Resultant F22 Diagram (ENV_ELU - Min)
KN, m, C

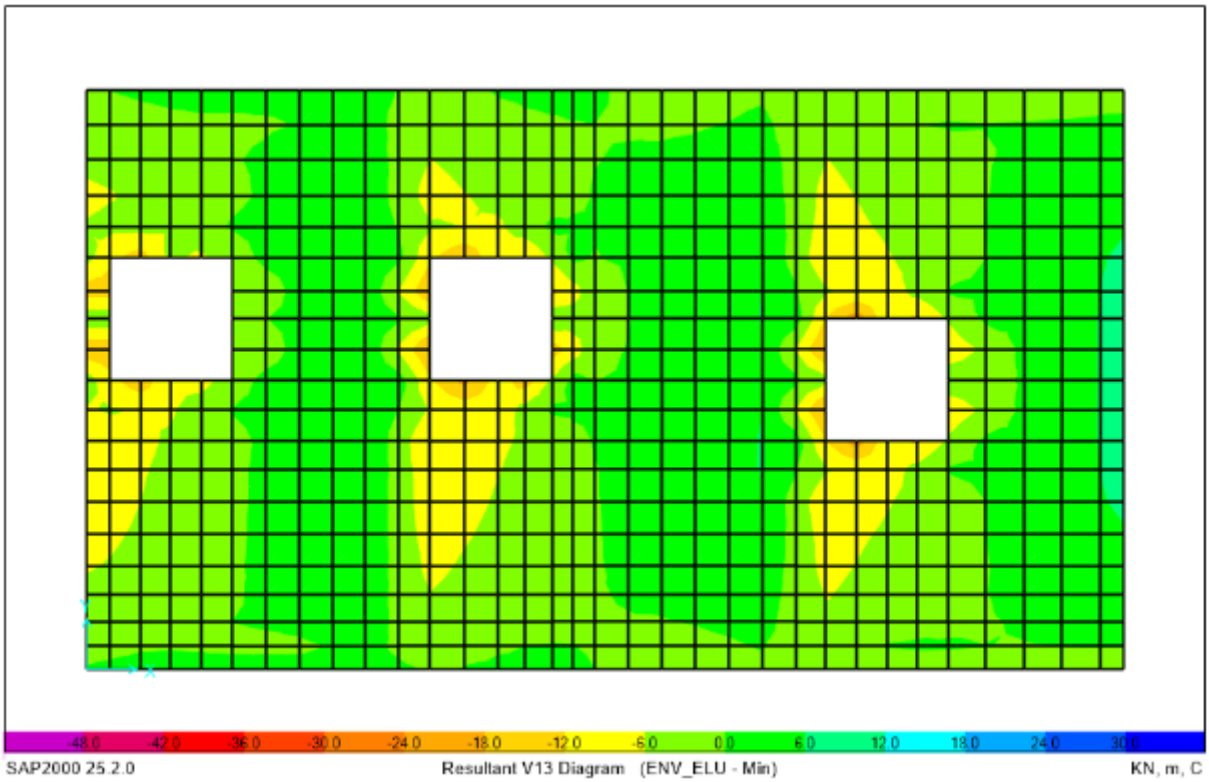

-117 -104 -91 -78 -65 -52 -39 -26 -13 0 13 26 39 52
SAP2000 25.2.0
Resultant F22 Diagram (ENV_ELU - Max)
KN, m, C

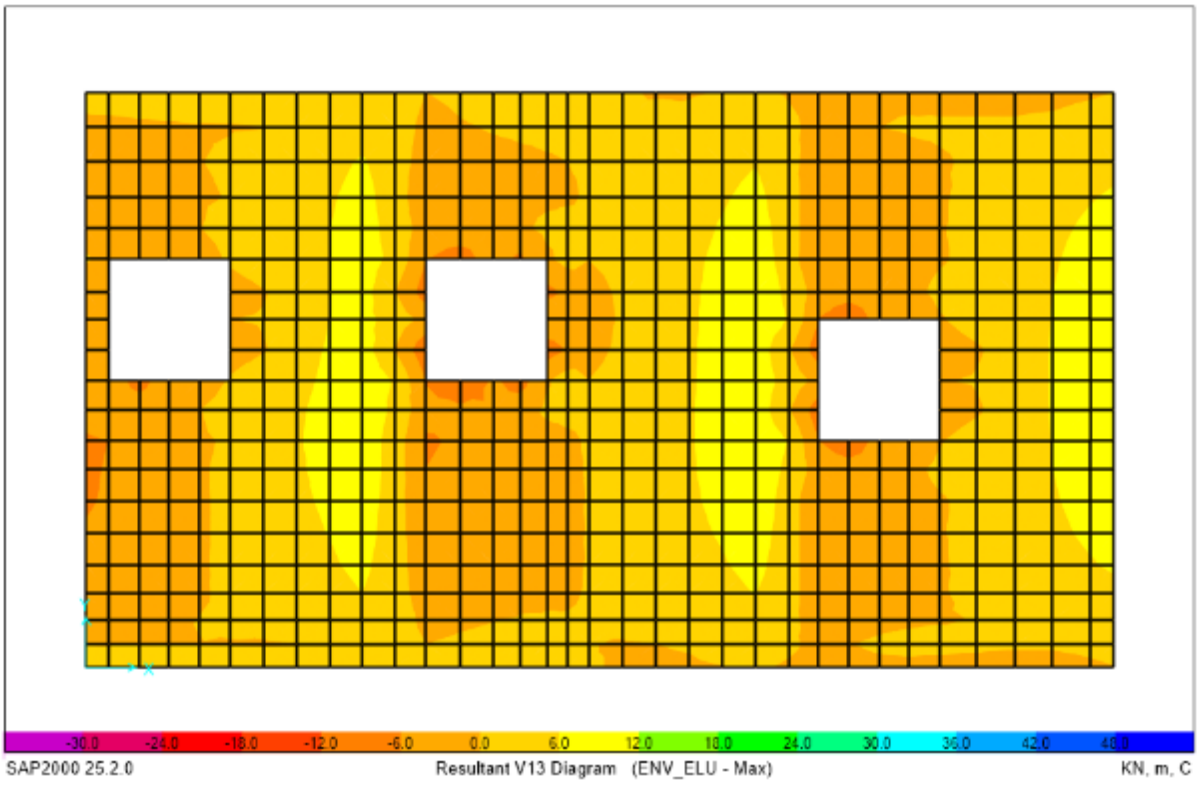

-13.6 -11.9 -10.2 -8.5 -6.8 -5.1 -3.4 -1.7 0.0 1.7 3.4 5.1 6.8 8.5
SAP2000 25.2.0
Resultant M11 Diagram (ENV_ELU - Min)
KN, m, C

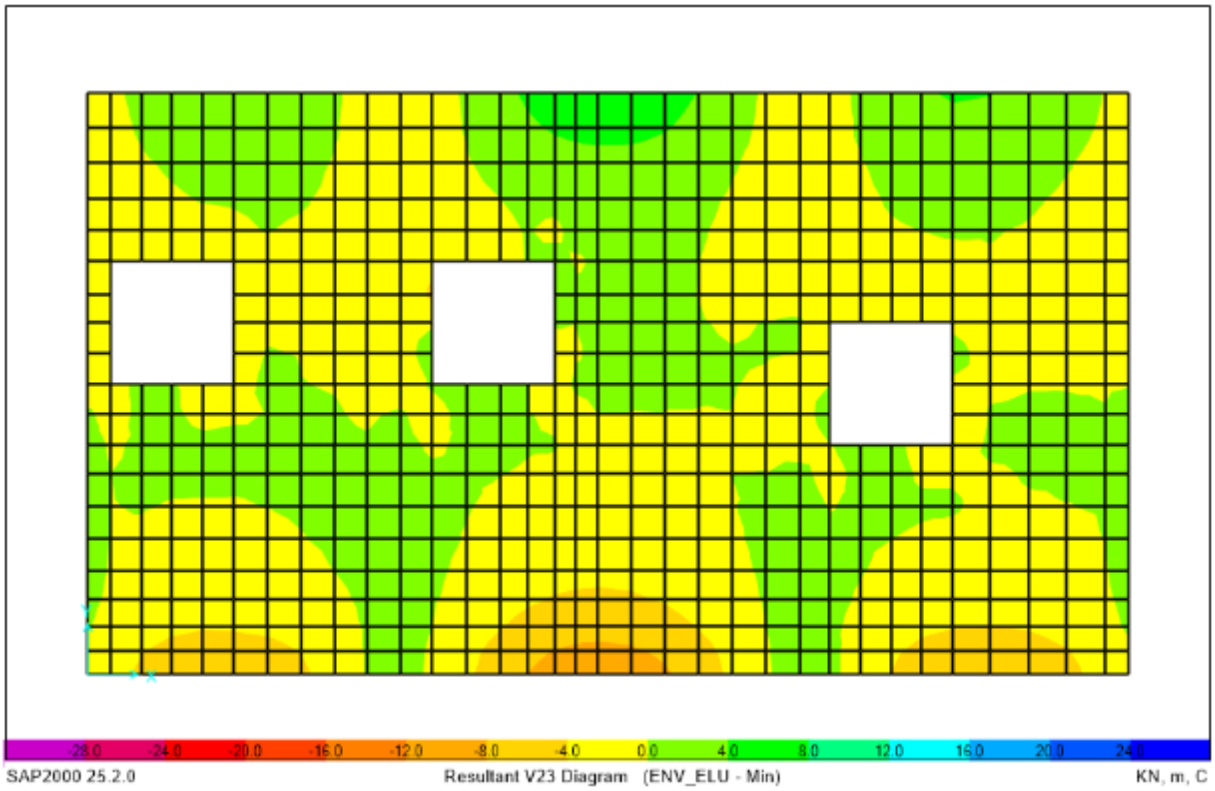

-7.6 -5.7 -3.8 -1.9 0.0 1.9 3.8 5.7 7.6 9.5 11.4 13.3 15.2 17.1
SAP2000 25.2.0
Resultant M11 Diagram (ENV_ELU - Max)
KN, m, C

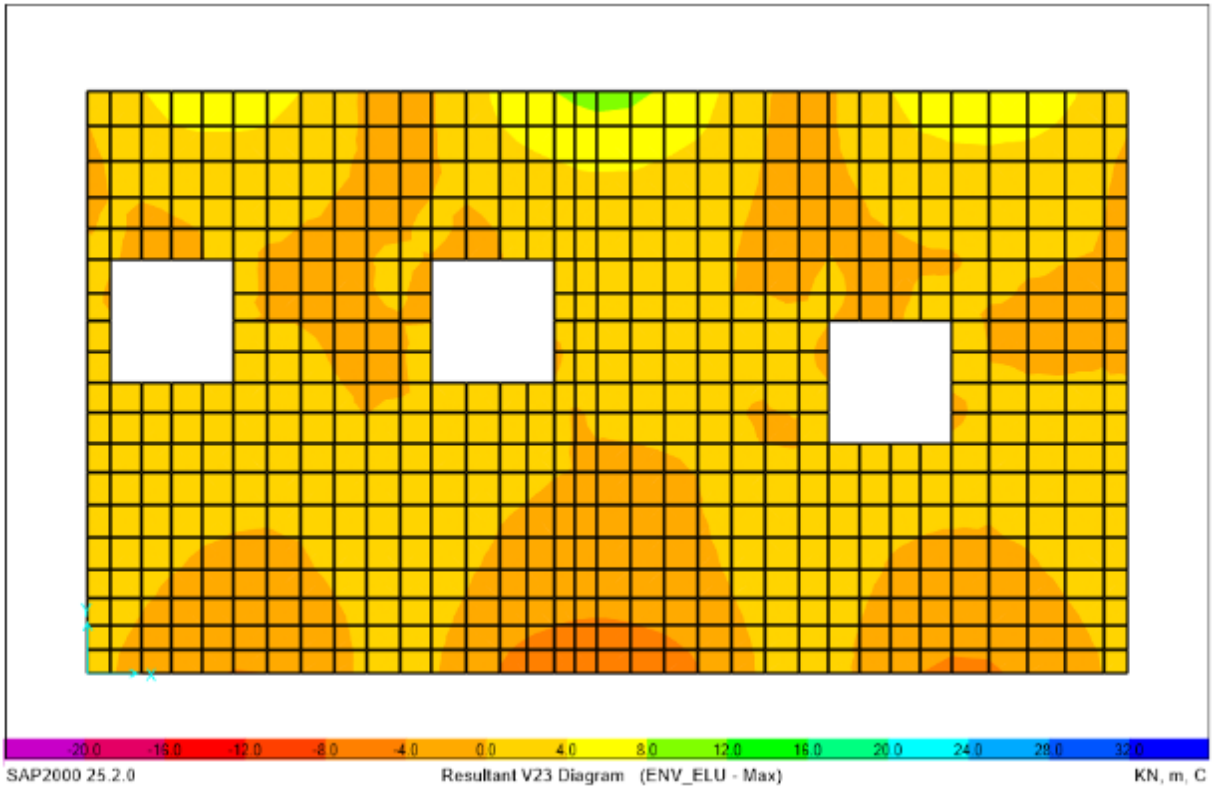

-13.2 -12.0 -10.8 -9.6 -8.4 -7.2 -6.0 -4.8 -3.6 -2.4 -1.2 0.0 1.2 2.4
SAP2000 25.2.0
Resultant M22 Diagram (ENV_ELU - Min)
KN, m, C


-7.20 -6.00 -4.80 -3.60 -2.40 -1.20 0.00 1.20 2.40 3.60 4.80 6.00 7.20 8.40
SAP2000 25.2.0
Resultant M22 Diagram (ENV_ELU - Max)
KN, m, C


-48.0 -42.0 -36.0 -30.0 -24.0 -18.0 -12.0 -6.0 0.0 6.0 12.0 18.0 24.0 30.0
SAP2000 25.2.0
Resultant V13 Diagram (ENV_ELU - Min)
KN, m, C


-30.0 -24.0 -18.0 -12.0 -6.0 0.0 6.0 12.0 18.0 24.0 30.0 36.0 42.0 48.0
SAP2000 25.2.0
Resultant V13 Diagram (ENV_ELU - Max)
KN, m, C


-28.0 -24.0 -20.0 -16.0 -12.0 -8.0 -4.0 0.0 4.0 8.0 12.0 16.0 20.0 24.0
SAP2000 25.2.0
Resultant V23 Diagram (ENV_ELU - Min)
KN, m, C


-20.0 -16.0 -12.0 -8.0 -4.0 0.0 4.0 8.0 12.0 16.0 20.0 24.0 28.0 32.0
SAP2000 25.2.0
Resultant V23 Diagram (ENV_ELU - Max)
KN, m, C

### 3.11.4 Verificaciones Estado Límite Último (ELU)

#### Losa base inferior

Se propone el siguiente armado:

| ARMADO LOSA BASE INFERIOR | | |
|---|---|---|
| Armadura longitudinal/transversal (cara superior) | Armadura longitudinal/transversal (cara inferior) | Armadura de cortante |
| Ø16@200mm (10.05cm$^2$/m) | Ø16@200mm (10.05cm$^2$/m) | No requerida |

| FLEXURE REINFORCEMENT CALCULATION | | |
|---|---|---|
| REF: EN-1992-1-1 | | |
| **Section inputs & material** | | |
| Flexure design moment | $M_d$ (KNm) | 17.33 |
| Section width | b (mm) | 1000 |
| Section heigth | h(mm) | 600 |
| Minimum cover | r (mm) | 50 |
| Effective section heigth | d (mm) | 542 |
| Specified compressive strength of concrete | $f_{ck}$(N/mm$^2$) | 25 |
| Coeff. for long term effects in compressive strength (chapter 3.1.6 EN-1992-1-1) | $a_{cc}$ | 0.85 |
| Partial factor for concrete, table 2.1N | $\gamma_c$ | 1.5 |
| Design value of concrete compressive strength $f_{cd} = \alpha_{cc} f_{ck} / \gamma_C$ | $f_{cd}$ (N/mm$^2$) | 14.17 |
| Mean tensile strength (according to table 3.1 EN 1992-1-1) | $f_{ctm}$ (N/mm$^2$) | 2.6 |
| Specified yield strength of reinforcement | $f_{yk}$ (N/mm$^2$) | 500 |
| Partial factor for reinforcing, table 2.1N | $\gamma_s$ | 1.15 |
| Design yield strength of reinforcement | $f_{yd}$ (N/mm$^2$) | 435 |
| Modulus of elasticity of reinforcement | $E_s$ (N/mm$^2$) | 200000 |
| for $f_{ck}$ < 50MPa (3.19) | l | 0.8 |
| for $f_{ck}$ < 50MPa (3.21) | h | 1.00 |
| | $k_1$ | 0.44 |
| | $k_2$ | 1.25 |
| (for $f_{ck}$ < 50MPa )Ultimate concrete strain (table 3.1) | $e_{cu2}$ | 0.0035 |
| Ratio of the redistributed moment to the elastic bending moment | d | 1.00 |
| | $(x/d)_{lim}$ | 0.45 |
| Strain in concrete, max value (table 3.1) | $\varepsilon_c$ (max) | 0.0035 |
| Strain in concrete, min value (table 3.1) | $\varepsilon_c$ (min) | 0.00175 |
| Normalized moment | m | 0.0042 |
| Normalized section capacity as a singly reinforced beam | $m_{lim}$ | 0.2942 |
| | $x_{lim}$(mm) | 242.8160 |
| **Reinforcement** | | |
| | If m<$m_{lim}$: | **APPLIED** |
| Normalized steel ratio | w | 0.00417 |
| Longitudinal reinforcement area in tensile | $A_s$ (cm$^2$) | 0.737 |
| | If m>$m_{lim}$: | **NOT APPLIED** |
| | $w_{lim}$ | 0.3584 |
| Depth to the compression steel, measured from the concrete compression face | d´ (mm) | 58 |
| | w´ | -0.324763839 |
| | w | 0.033636161 |
| Stress in the compression steel | $f_s$´ (N/mm$^2$) | 434.7826087 |
| Longitudinal reinforcement area in compression | $A_s$´(cm$^2$) (up for $M_d$+) | Not required |
| Longitudinal reinforcement area in tensile | $A_s$ (cm$^2$) (bottom for $M_d$+) | 5.94 |

| | | |
|---|---|---|
| OVERALL Required Md | $A_s'$ ($cm^2$) (up for $M_d$ +) | 0.000 |
| OVERALL Required Md | $A_s$ ($cm^2$)(bottom for $M_d$ +) | 0.737 |
| The tensile is in both faces | T (kN) | 14.8 |
| Shear effort (6.2.3 (7), EN-1992-1-1) | $V_E$ (kN) | 0 |
| Reinf. in each face | $A_s$ ($cm^2$) | 0.170 |
| Total necessary reinf. In top face | $A_s$ ($cm^2$)(TOTAL) | **0.17** |
| Total necessary reinf. In low face (tensile face) | $A_s$ ($cm^2$)(TOTAL) | **0.91** |

**Disposed reinforcement:**

| | | |
|---|---|---|
| Diameter of bar | ϕ (mm) | 16 |
| Bar spacing | s (m) | 200 |
| Nº of reinf.layers | n | 1 |
| Area provided | A ($cm^2$) | 10.053 |
| | additional reinforcement | |
| Diameter of bar | ϕ (mm) | 0 |
| Bar spacing | s (m) | 200 |
| Area provided | A ($cm^2$) | 0.000 |
| | $A_{total}$ ($cm^2$) | 10.053 |
| | **OK Flexure** | **9%** |
| | - | - |
| - | - | - |

**Minimum reinforcement EN-1992-1-1**

| | | |
|---|---|---|
| | Section type | SLAB/FOUNDATION |
| | minimum ratio | **0.001352** |
| Minimum reinforcement for each face | $As_{min}$ ($cm^2$) | 7.328 |
| - | - | - |
| Reinforcement provided | $A_{total}$ ($cm^2$) | **10.05** |
| | **OK Minimum reinforcement** | **73%** |

**Maximum reinforcement EN-1992-1-1**

| | | |
|---|---|---|
| | maximum ratio | **0.040** |
| | $As_{max}$ ($cm^2$) | 240 |
| | **OK maximum reinforcement** | **4%** |
| | $s_{max}$ (mm) | 400 |
| | | **OK** |

| SHEAR REINFORCEMENT CALCULATION | | | |
|---|---|---|---|
| | | | EN 1992-1 AND EN 1992-2 |
| **Geometry and materials** | | | |
| Overall depth of the cross section | $h$ | [m] | 0.60 |
| Distance from the tension fiber to the centroid of the tensile reinforcement | $d'$ | [m] | 0.05 |
| Effective depth | $d$ | [m] | 0.55 |
| Smallest width of the cross section in the tensile area | $b_w$ | [m] | 1.00 |
| Number of grouted metal ducts in the web | $N_{ducts}$ | | 0 |
| Diamenter of the duct | $\phi_{duct}$ | [mm] | 0 |
| Nominal web thickness considering the PT ducts | $b_{w,nom}$ | [m] | 1.00 |
| Characteristic compressive cylinder strength of concrete at 28 days | $f_{ck}$ | [MPa] | 25 |
| Partial factor for concrete | $\gamma_c$ | | 1.2 |
| Characteristic yield strength of shear reinforcement | $f_{ywk}$ | [MPa] | 500 |
| Partial factor for reinforcing steel | $\gamma_s$ | | 1 |
| Area of tensile reinforcement | $A_{sl}$ | [$cm^2$] | 10.05 |
| Area of concrete cross section | $A_c$ | [$m^2$] | 0.60 |
| **Forces** | | | |
| Axial force in the cross section due to loading or the acing effect of prestressing ($N_{Ed}$ > 0 for compression) | $N_{Ed}$ | [kN] | -31.0 |
| Design value of the applied shear force | $V_{Ed}$ | [kN] | 53.8 |
| **Members not requiring shear reinforcement** | | | |
| | $k$ | | 1.6 |
| | $\rho_l$ | | 0.0018 |
| | $\sigma_{cp}$ | [MPa] | -0.05 |
| | $C_{Rd,c}$ | | 0.15 |
| | $v_{min}$ | [MPa] | 0.36 |
| | $k_1$ | | 0.15 |
| Design value for the shear resistance | **$V_{Rd,c}$** | **[kN]** | **215.2** |

## Muros

Se propone el siguiente armado:

| ARMADO MUROS | | |
|---|---|---|
| Armadura longitudinal/transversal (cara externa) | Armadura longitudinal/transversal (cara interna) | Armadura de cortante |
| Ø12@200mm (5,65cm²/m) | Ø12@200mm (5,65cm²/m) | No requiere armado a cortante |

| FLEXURE REINFORCEMENT CALCULATION | | |
|---|---|---|
| REF: EN-1992-1-1 | | |
| **Section inputs & material** | | |
| Flexure design moment | $M_d$ (KNm) | 11 |
| Section width | b (mm) | 1000 |
| Section heigth | h(mm) | 300 |
| Minimum cover | r (mm) | 50 |
| Effective section heigth | d (mm) | 244 |
| Specified compressive strength of concrete | $f_{ck}$(N/mm²) | 25 |
| Coeff. for long term effects in compressive strength (chapter 3.1.6 EN-1992-1-1) | $a_{cc}$ | 0.85 |
| Partial factor for concrete, table 2.1N | $\gamma_c$ | 1.5 |
| Design value of concrete compressive strength $f_{cd} = \alpha_{cc} f_{ck} / \gamma_C$ | $f_{cd}$ (N/mm²) | 14.17 |
| Mean tensile strength (according to table 3.1 EN 1992-1-1) | $f_{ctm}$ (N/mm²) | 2.6 |
| Specified yield strength of reinforcement | $f_{yk}$ (N/mm²) | 500 |
| Partial factor for reinforcing, table 2.1N | $\gamma_s$ | 1.15 |
| Design yield strength of reinforcement | $f_{yd}$ (N/mm²) | 435 |
| Modulus of elasticity of reinforcement | $E_s$ (N/mm²) | 200000 |
| for $f_{ck}$ < 50MPa (3.19) | l | 0.8 |
| for $f_{ck}$ < 50MPa (3.21) | h | 1.00 |
| | $k_1$ | 0.44 |
| | $k_2$ | 1.25 |
| (for $f_{ck}$ < 50MPa )Ultimate concrete strain (table 3.1) | $e_{cu2}$ | 0.0035 |
| Ratio of the redistributed moment to the elastic bending moment | d | 1.00 |
| | $(x/d)_{lim}$ | 0.45 |
| Strain in concrete, max value (table 3.1) | $\varepsilon_c$ (max) | 0.0035 |
| Strain in concrete, min value (table 3.1) | $\varepsilon_c$ (min) | 0.00175 |
| Normalized moment | m | 0.0130 |
| Normalized section capacity as a singly reinforced beam | $m_{lim}$ | 0.2942 |
| | $x_{lim}$(mm) | 109.3120 |
| **Reinforcement** | | |
| | If m<$m_{lim}$: | **APPLIED** |
| Normalized steel ratio | w | 0.01313 |
| Longitudinal reinforcement area in tensile | $A_s$ (cm²) | 1.044 |
| | If m>$m_{lim}$: | **NOT APPLIED** |
| | $w_{lim}$ | 0.3584 |
| Depth to the compression steel, measured from the concrete compression face | d´ (mm) | 56 |
| | w´ | -0.364874336 |
| | w | -0.006474336 |
| Stress in the compression steel | $f_s$´ (N/mm²) | 341.3934426 |
| Longitudinal reinforcement area in compression | $A_s$´(cm²) (up for $M_d$+) | Not required |
| Longitudinal reinforcement area in tensile | $A_s$ (cm²) (bottom for $M_d$+) | -0.51 |

| | | |
|---|---|---|
| OVERALL Required Md | $A_s'$ ($cm^2$) (up for $M_d$ +) | 0.000 |
| OVERALL Required Md | $A_s$ ($cm^2$)(bottom for $M_d$ +) | 1.044 |
| The tensile is in both faces | T (kN) | 51 |
| Shear effort (6.2.3 (7), EN-1992-1-1) | $V_E$ (kN) | 0 |
| Reinf. in each face | $A_s$ ($cm^2$) | 0.587 |
| Total necessary reinf. In top face | $A_s$ ($cm^2$)(TOTAL) | **0.59** |
| Total necessary reinf. In low face (tensile face) | $A_s$ ($cm^2$)(TOTAL) | **1.63** |

**Disposed reinforcement:**

| | | |
|---|---|---|
| Diameter of bar | ϕ (mm) | 12 |
| Bar spacing | s (m) | 200 |
| Nº of reinf.layers | n | 1 |
| Area provided | A ($cm^2$) | 5.655 |
| | additional reinforcement | |
| Diameter of bar | ϕ (mm) | 0 |
| Bar spacing | s (m) | 200 |
| Area provided | A ($cm^2$) | 0.000 |
| | $A_{total}$ ($cm^2$) | 5.655 |
| | **OK Flexure** | **29%** |
| | - | - |
| - | - | - |

**Minimum reinforcement EN-1992-1-1**

| | | |
|---|---|---|
| | Section type | WALL (horizontal) |
| | minimum ratio | **0.001600** |
| Minimum reinforcement for each face | $As_{min}$ ($cm^2$) | 3.904 |
| - | - | - |
| Reinforcement provided | $A_{total}$ ($cm^2$) | **5.65** |
| | **OK Minimum reinforcement** | **69%** |

**Maximum reinforcement EN-1992-1-1**

| | | |
|---|---|---|
| | maximum ratio | **0.040** |
| | $As_{max}$ ($cm^2$) | 120 |
| | **OK maximum reinforcement** | **5%** |
| | $s_{max}$ (mm) | 400 |
| | | **OK** |

| SHEAR REINFORCEMENT CALCULATION | | | |
|---|---|---|---|
| | | | EN 1992-1 AND EN 1992-2 |
| **Geometry and materials** | | | |
| Overall depth of the cross section | h | [m] | 0.30 |
| Distance from the tension fiber to the centroid of the tensile reinforcement | d' | [m] | 0.05 |
| Effective depth | d | [m] | 0.25 |
| Smallest width of the cross section in the tensile area | $b_w$ | [m] | 1.00 |
| Number of grouted metal ducts in the web | $N_{ducts}$ | | 0 |
| Diamenter of the duct | $\phi_{duct}$ | [mm] | 0 |
| Nominal web thickness considering the PT ducts | $b_{w,nom}$ | [m] | 1.00 |
| Characteristic compressive cylinder strength of concrete at 28 days | $f_{ck}$ | [MPa] | 25 |
| Partial factor for concrete | $\gamma_c$ | | 1.2 |
| Characteristic yield strength of shear reinforcement | $f_{ywk}$ | [MPa] | 500 |
| Partial factor for reinforcing steel | $\gamma_s$ | | 1 |
| Area of tensile reinforcement | $A_{sl}$ | [$cm^2$] | 5.65 |
| Area of concrete cross section | $A_c$ | [$m^2$] | 0.30 |
| **Forces** | | | |
| Axial force in the cross section due to loading or the acing effect of prestressing ($N_{Ed}$ > 0 for compression) | $N_{Ed}$ | [kN] | -71.0 |
| Design value of the applied shear force | $V_{Ed}$ | [kN] | 53.6 |
| **Members not requiring shear reinforcement** | | | |
| | k | | 1.9 |
| | $\rho_l$ | | 0.0023 |
| | $\sigma_{cp}$ | [MPa] | -0.24 |
| | $C_{Rd,c}$ | | 0.15 |
| | $v_{min}$ | [MPa] | 0.46 |
| | $k_1$ | | 0.15 |
| Design value for the shear resistance | **$V_{Rd,c}$** | **[kN]** | **117.7** |

## Losa superior

| ARMADO LOSA SUPERIOR | | |
|---|---|---|
| Armadura longitudinal/transversal (cara externa) | Armadura longitudinal/transversal (cara interna) | Armadura de cortante |
| Ø12@200mm (5,65cm²/m) | Ø12@200mm (5,65cm²/m) | No requiere armado a cortante |

**FLEXURE REINFORCEMENT CALCULATION**

REF: EN-1992-1-1

**Section inputs & material**

| | | |
|---|---|---|
| Flexure design moment | $M_d$ (KNm) | 8.5 |
| Section width | b (mm) | 1000 |
| Section heigth | h(mm) | 300 |
| Minimum cover | r (mm) | 50 |
| Effective section heigth | d (mm) | 244 |
| Specified compressive strength of concrete | $f_{ck}$(N/mm²) | 25 |
| Coeff. for long term effects in compressive strength (chapter 3.1.6 EN-1992-1-1) | $a_{cc}$ | 0.85 |
| Partial factor for concrete, table 2.1N | $\gamma_c$ | 1.5 |
| Design value of concrete compressive strength $f_{cd} = \alpha_{cc} f_{ck} / \gamma_C$ | $f_{cd}$ (N/mm²) | 14.17 |
| Mean tensile strength (according to table 3.1 EN 1992-1-1) | $f_{ctm}$ (N/mm²) | 2.6 |
| Specified yield strength of reinforcement | $f_{yk}$ (N/mm²) | 500 |
| Partial factor for reinforcing, table 2.1N | $\gamma_s$ | 1.15 |
| Design yield strength of reinforcement | $f_{yd}$ (N/mm²) | 435 |
| Modulus of elasticity of reinforcement | $E_s$ (N/mm²) | 200000 |
| for $f_{ck}$ < 50MPa (3.19) | l | 0.8 |
| for $f_{ck}$ < 50MPa (3.21) | h | 1.00 |
| | $k_1$ | 0.44 |
| | $k_2$ | 1.25 |
| (for $f_{ck}$ < 50MPa )Ultimate concrete strain (table 3.1) | $e_{cu2}$ | 0.0035 |
| Ratio of the redistributed moment to the elastic bending moment | d | 1.00 |
| | $(x/d)_{lim}$ | 0.45 |
| Strain in concrete, max value (table 3.1) | $\varepsilon_c$ (max) | 0.0035 |
| Strain in concrete, min value (table 3.1) | $\varepsilon_c$ (min) | 0.00175 |
| Normalized moment | m | 0.0101 |
| Normalized section capacity as a singly reinforced beam | $m_{lim}$ | 0.2942 |
| | $x_{lim}$(mm) | 109.3120 |

**Reinforcement**

| | | |
|---|---|---|
| | If m<$m_{lim}$: | **APPLIED** |
| Normalized steel ratio | w | 0.01013 |
| Longitudinal reinforcement area in tensile | $A_s$ (cm²) | 0.805 |
| | If m>$m_{lim}$: | **NOT APPLIED** |
| | $w_{lim}$ | 0.3584 |
| Depth to the compression steel, measured from the concrete compression face | d´ (mm) | 56 |
| | w´ | -0.368721358 |
| | w | -0.010321358 |
| Stress in the compression steel | $f_s$´ (N/mm²) | 341.3934426 |
| Longitudinal reinforcement area in compression | $A_s$´(cm²) (up for $M_d$+) | Not required |
| Longitudinal reinforcement area in tensile | $A_s$ (cm²) (bottom for $M_d$+) | -0.82 |

| | | |
|---|---|---|
| OVERALL Required Md | $A_s'$ ($cm^2$) (up for $M_d$ +) | 0.000 |
| OVERALL Required Md | $A_s$ ($cm^2$)(bottom for $M_d$ +) | 0.805 |
| The tensile is in both faces | T (kN) | 28 |
| Shear effort (6.2.3 (7), EN-1992-1-1) | $V_E$ (kN) | 0 |
| Reinf. in each face | $A_s$ ($cm^2$) | 0.322 |
| Total necessary reinf. In top face | $A_s$ ($cm^2$)(TOTAL) | **0.32** |
| Total necessary reinf. In low face (tensile face) | $A_s$ ($cm^2$)(TOTAL) | **1.13** |

**Disposed reinforcement:**

| | | |
|---|---|---|
| Diameter of bar | ϕ (mm) | 12 |
| Bar spacing | s (m) | 200 |
| Nº of reinf.layers | n | 1 |
| Area provided | A ($cm^2$) | 5.655 |
| | additional reinforcement | |
| Diameter of bar | ϕ (mm) | 0 |
| Bar spacing | s (m) | 200 |
| Area provided | A ($cm^2$) | 0.000 |
| | $A_{total}$ ($cm^2$) | 5.655 |
| | **OK Flexure** | **20%** |
| | - | - |
| - | - | - |

**Minimum reinforcement EN-1992-1-1**

| | | |
|---|---|---|
| | Section type | SLAB/FOUNDATION |
| | minimum ratio | **0.001352** |
| Minimum reinforcement for each face | $As_{min}$ ($cm^2$) | 3.299 |
| - | - | - |
| Reinforcement provided | $A_{total}$ ($cm^2$) | **5.65** |
| | **OK Minimum reinforcement** | **58%** |

**Maximum reinforcement EN-1992-1-1**

| | | |
|---|---|---|
| | maximum ratio | **0.040** |
| | $As_{max}$ ($cm^2$) | 120 |
| | **OK maximum reinforcement** | **5%** |
| | $s_{max}$ (mm) | 400 |
| | | **OK** |

| SHEAR REINFORCEMENT CALCULATION | | | |
|---|---|---|---|
| | | | EN 1992-1 AND EN 1992-2 |
| **Geometry and materials** | | | |
| Overall depth of the cross section | h | [m] | 0.30 |
| Distance from the tension fiber to the centroid of the tensile reinforcement | d' | [m] | 0.05 |
| Effective depth | d | [m] | 0.25 |
| Smallest width of the cross section in the tensile area | $b_w$ | [m] | 1.00 |
| Number of grouted metal ducts in the web | $N_{ducts}$ | | 0 |
| Diamenter of the duct | $\phi_{duct}$ | [mm] | 0 |
| Nominal web thickness considering the PT ducts | $b_{w,nom}$ | [m] | 1.00 |
| Characteristic compressive cylinder strength of concrete at 28 days | $f_{ck}$ | [MPa] | 25 |
| Partial factor for concrete | $\gamma_c$ | | 1.2 |
| Characteristic yield strength of shear reinforcement | $f_{ywk}$ | [MPa] | 500 |
| Partial factor for reinforcing steel | $\gamma_s$ | | 1 |
| Area of tensile reinforcement | $A_{sl}$ | [$cm^2$] | 5.65 |
| Area of concrete cross section | $A_c$ | [$m^2$] | 0.30 |
| **Forces** | | | |
| Axial force in the cross section due to loading or the acing effect of prestressing ($N_{Ed}$ > 0 for compression) | $N_{Ed}$ | [kN] | -18.0 |
| Design value of the applied shear force | $V_{Ed}$ | [kN] | 27.0 |
| **Members not requiring shear reinforcement** | | | |
| | k | | 1.9 |
| | $\rho_l$ | | 0.0023 |
| | $\sigma_{cp}$ | [MPa] | -0.06 |
| | $C_{Rd,c}$ | | 0.15 |
| | $v_{min}$ | [MPa] | 0.46 |
| | $k_1$ | | 0.15 |
| Design value for the shear resistance | **$V_{Rd,c}$** | **[kN]** | **124.3** |

### 3.11.5 Verificación Estado Límite Servicio (ELS)

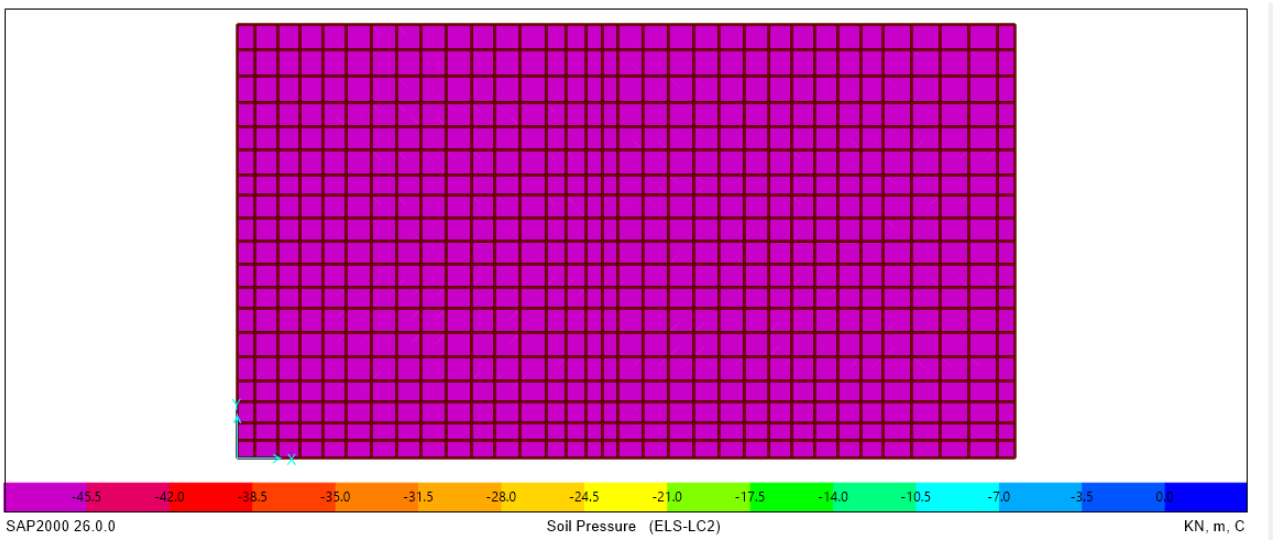
#### Comprobación abertura máxima de fisura

Se ha realizado una comprobación del máximo momento de fisuración por cada sección. A continuación, se proporciona un resumen del momento máximo resistente y del momento solicitado por tipo de sección:

| COMPROBACIÓN A FISURACIÓN | | |
|---|---|---|
| **Sección** | **$M_d$ (kNm)** | **$M_R$ (kNm)** |
| Losa base inferior | 29 | 192,60 |
| Muros | 15 | 48,15 |
| Losa superior | 7 | 48,15 |

#### Tensión máxima transmitida al terreno

La tensión máxima transmitida al terreno es de 45 kN/m².


-45.5
-42.0
-38.5
-35.0
-31.5
-28.0
-24.5
-21.0
-17.5
-14.0
-10.5
-7.0
-3.5
0.0
SAP2000 26.0.0
Soil Pressure (ELS-LC2)
KN, m, C

# 4. FIRMAS

POZUELO DE ALARCÓN, MAYO DE 2024

| **Ingeniero Autor del Anejo** | **Ingeniero Autor del Proyecto** | **Ingeniero Autor del Proyecto** |
|---|---|---|
| Fdo. Dr. Antonio José Madrid Ramos<br>Ing. De Caminos, Canales y Puertos<br>Colegiado Nº 10.764 | Fdo. D. Roberto Pillado González<br>Ing. De Caminos, Canales y Puertos<br>Colegiado Nº 18.679 | Fdo. Dr. Manuel Mudarra Hernández<br>Ing. de Caminos, Canales y Puertos<br>Colegiado Nº 35.493 |