

## Analysis using finite element method

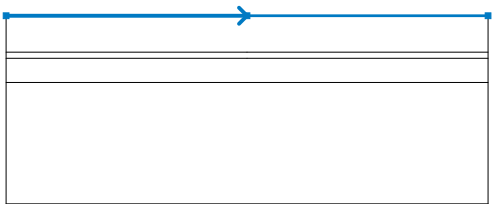
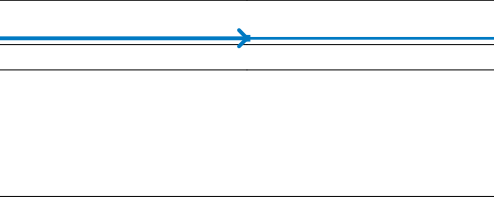
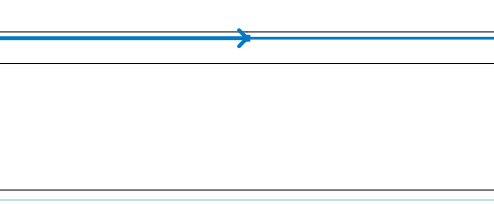
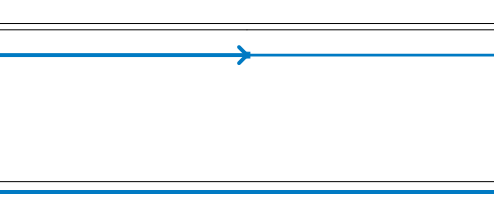
### Topology

#### Проект

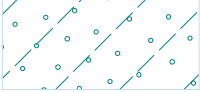

Дата : 11.09.2008

Project type : Plane strain  
 Analysis type : Stress  
 Tunnels : no  
 Enhanced input : no  
 Statistic : no  
 Concrete structures : CSN 73 1201 R  
 Steel structures : CSN 73 1401

#### Граница контура

№	Распол.гран.контура	Коорд.точек гр.контура [м]					
		x	z	x	z	x	z
1		-20,00	0,00	0,00	0,00	20,00	0,00
2		-20,00	-3,00	0,00	-3,00	20,00	-3,00
3		-20,00	-3,50	0,00	-3,50	20,00	-3,50
4		-20,00	-5,50	0,00	-5,50	20,00	-5,50

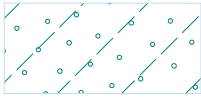

#### Soil parameters - basic data

№	Имя	Sample	$\gamma$ [кН/м <sup>3</sup> ]	$\nu$ [-]	E [МПа]	$\alpha$ [-]	$K_e$ [МПа]
1	S4		18,00	0,30	10,00	1,00	
2	Тшнда F6, konzistence tuhб		21,00	0,40	4,50	1,00	

### Soil parameters - data according to model

№	Модель в железе	$C_{eff}$ [кПа]	$\phi_{eff}$ [°]	$\psi$ [°]
1	Mohr - Coulomb модифиц.	4,00	29,00	0,00
2	Mohr - Coulomb модифиц.	10,00	19,00	0,00

### Soil parameters - uplift

№	Имя	Sample	$\gamma_{sat}$ [кН/м <sup>3</sup> ]	$\gamma_s$ [кН/м <sup>3</sup> ]	$n$ [-]
1	S4		18,00		
2	Тшнда F6, konzistence tuhб		21,00		

### Параметры грунтов

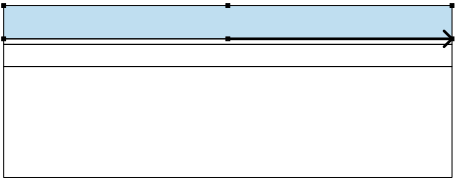
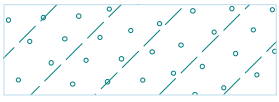
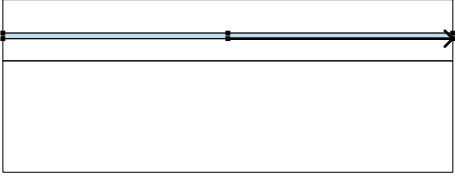

#### S4

Модель в железе : Mohr - Coulomb модифиц.  
 Удельный вес :  $\gamma$  = 18,00 кН/м<sup>3</sup>  
 коэфф.Пуассона :  $\nu$  = 0,30  
 Модуль упруг. : E = 10,00 МПа  
 Угол внутреннего трения :  $\phi_{eff}$  = 29,00 °  
 Связность грунта :  $C_{eff}$  = 4,00 кПа  
 Угол дилатанции :  $\psi$  = 0,00 °  
 Удельный вес нас.грунта :  $\gamma_{sat}$  = 18,00 кН/м<sup>3</sup>

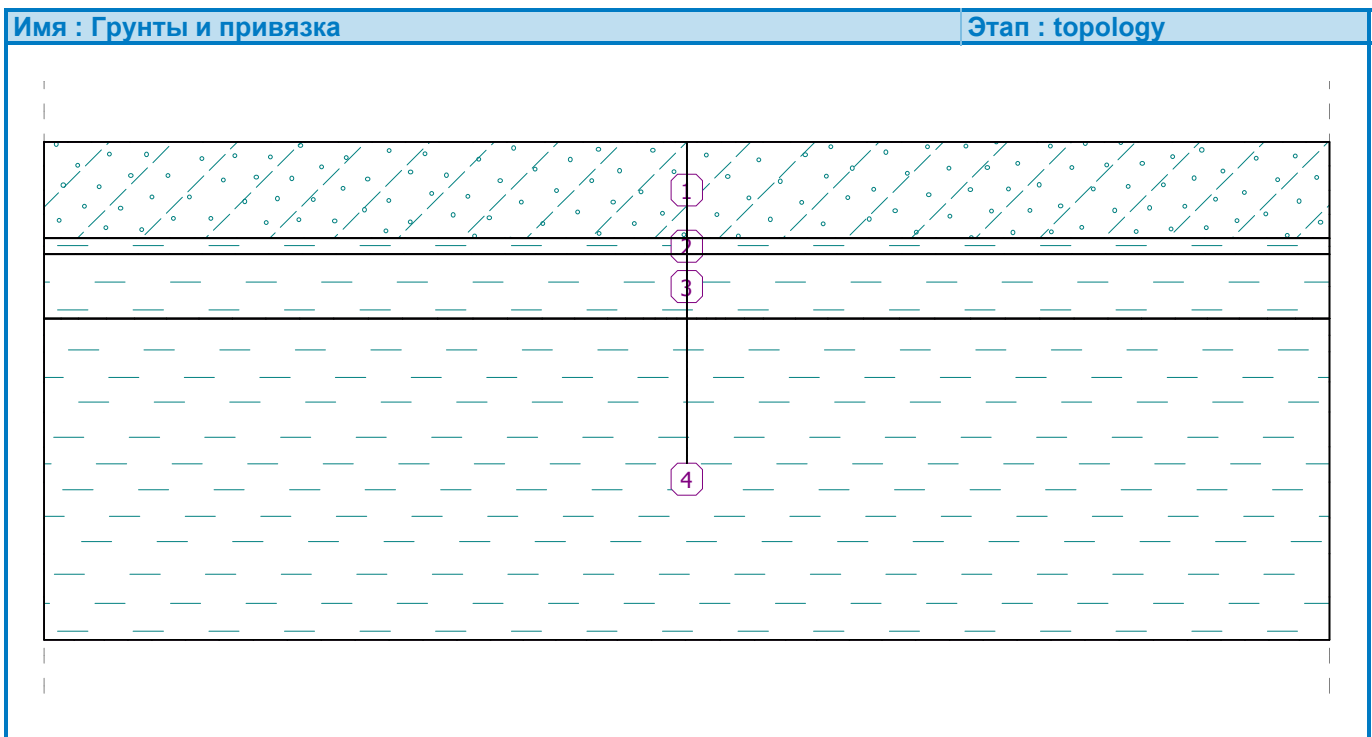
#### Тшнда F6, konzistence tuhб

Модель в железе : Mohr - Coulomb модифиц.  
 Удельный вес :  $\gamma$  = 21,00 кН/м<sup>3</sup>  
 коэфф.Пуассона :  $\nu$  = 0,40  
 Модуль упруг. : E = 4,50 МПа  
 Угол внутреннего трения :  $\phi_{eff}$  = 19,00 °  
 Связность грунта :  $C_{eff}$  = 10,00 кПа  
 Угол дилатанции :  $\psi$  = 0,00 °  
 Удельный вес нас.грунта :  $\gamma_{sat}$  = 21,00 кН/м<sup>3</sup>

### Привяз.и поверх-ти

№	Располож.поверх.	Коорд.точек поверхности [м]				Присвоенный грунт
		x	z	x	z	
1		0,00	-3,00	20,00	-3,00	S4 
		20,00	0,00	0,00	0,00	
		-20,00	0,00	-20,00	-3,00	
2		0,00	-3,50	20,00	-3,50	Тшнда F6, konzistence tuhб 
		20,00	-3,00	0,00	-3,00	
		-20,00	-3,00	-20,00	-3,50	

№	Располож.поверх.	Коорд.точек поверхности [м]				Присвоенный грунт
		x	z	x	z	
3		0,00	-5,50	20,00	-5,50	Тшнда F6, konzistence tuhб
		20,00	-3,50	0,00	-3,50	
		-20,00	-3,50	-20,00	-5,50	
4		0,00	-5,50	-20,00	-5,50	Тшнда F6, konzistence tuhб
		-20,00	-15,50	20,00	-15,50	
		20,00	-5,50			



**Типы контактов**

**Контакт раһенн zemina**

Material model : Mohr-Coulomb  
 Shear stiffness :  $K_s = 10000,00 \text{ кН/м}^3$   
 Normal stiffness :  $K_n = 10000,00 \text{ кН/м}^3$   
 Reduction c :  $\delta c = 0,30$   
 Reduction  $\mu$  :  $\delta \mu = 0,30$   
 Dilation angle :  $\psi = 0,00^\circ$   
 Tensile strength :  $R_t = 0,000 \text{ кПа}$

**Free points**

№	Location		№	Location		№	Location		№	Location	
	x [м]	z [м]		x [м]	z [м]		x [м]	z [м]		x [м]	z [м]
1	0,00	-10,00									

**Free lines**

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№	Type of line	Mode of input	Lines topology
1	segment		Origin (0,00; -10,00) [м] , end (0,00; 0,00) [м]

### Lines refinement

№	Location	Radius r [м]	Length l [м]
1	Free line No. 1	5,00	0,50

### Генер. сети

#### Mesh generation parameters

Element edge length : 2,00 [м]  
 Mesh smoothing : yes  
 Generate multinode elements : yes

#### Mesh generation result

**Finite element mesh was successfully generated.**

Number of nodes 1547  
 Number of elements 1022 (region 426, beam 149, interface 447)

### Исход.данные (Этап проект 1)

#### Assignment and activation

№	Region	Active / inactive	Assigned soil
1		Active	S4
2		Active	S4
3		Active	Тшнда F6, konzistence tuhб
4		Active	Тшнда F6, konzistence tuhб

№	Region	Active / inactive	Assigned soil
5		Active	Тшнда F6, konzistence tuhб 
6		Active	Тшнда F6, konzistence tuhб 
7		Active	Тшнда F6, konzistence tuhб 

### Line supports

№	Location	Support	
		Direction X	Direction Z
A1	Mesh line No. 15	fixed	free
A2	Mesh line No. 13	fixed	free
A3	Mesh line No. 9	fixed	free
A4	Mesh line No. 5	fixed	free
A5	Mesh line No. 17	fixed	free
A6	Mesh line No. 12	fixed	free
A7	Mesh line No. 8	fixed	free
A8	Mesh line No. 2	fixed	free
A9	Mesh line No. 16	fixed	fixed

A1 up to A9 - automatically generated line supports along model edges

### Вода

Тип воды : У.Г.В.

№	Располож.У.Г.В.	Координаты точек У.Г.В. [м]					
		x	z	x	z	x	z
1		-20,00	-3,00	0,00	-3,00	20,00	-3,00

### Analysis setting

#### General

Method : Newton - Raphson  
 Stiffness matrix change : after each iteration  
 Max. number of iterations for one calc. step : 50  
 Initial calculation step : 0,25  
 Displacement error : 0,0100

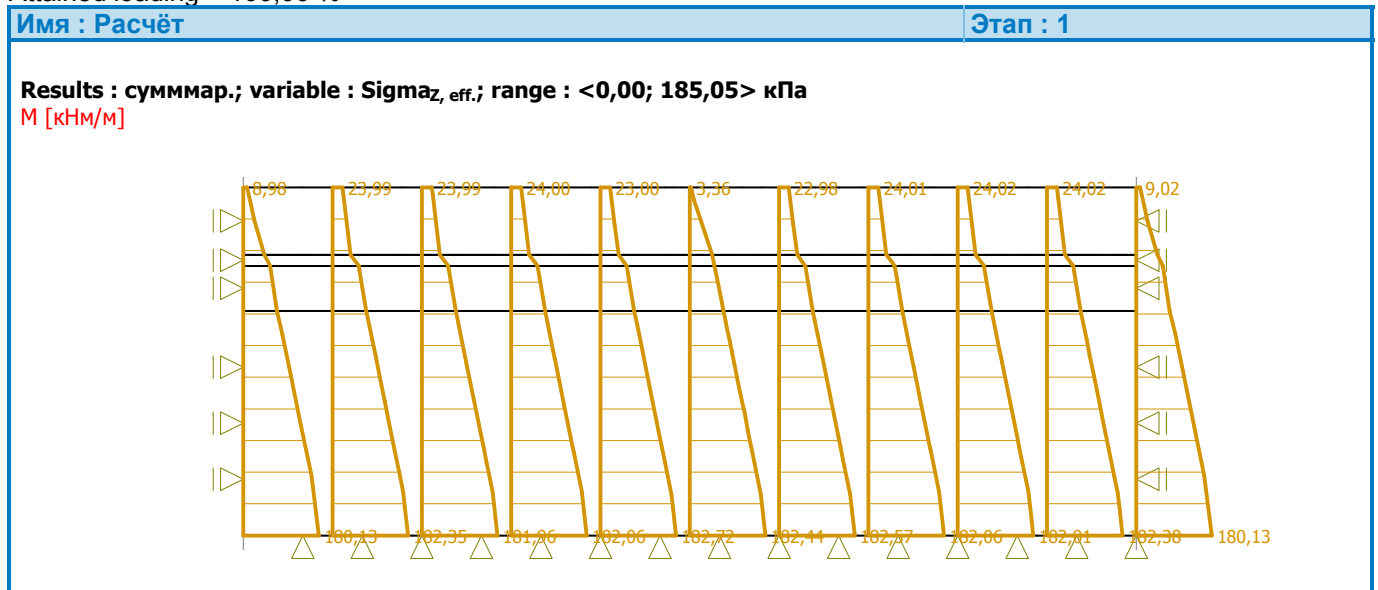
Imbalanced forces error :	0,0100
Energy error :	0,0100
Respect material interfaces :	NO
<b>Newton - Raphson</b>	
Relaxation factor :	2
Max. number of relaxations for one calc. step :	2
Min. number of iterations for one calc. step :	1
<b>Line search</b>	
Solution method :	iterate no
Line search limit - minimum :	0,100
Line search limit - maximum :	1,000
<b>Plasticity</b>	
Return mapping error :	0,00100
Max. number of iterations for one plast. step :	20

## Результаты (Эт.проект. 1)

Stress analysis was successfully completed.

Analysis setting : **user-defined**

Attained loading = 100,00 %



## Extremes

### Stress (extremes)

	Location		Min	Location		Max
	x [м]	z [м]		x [м]	z [м]	
$\Sigma_{z, \text{tot.}}$ [кПа]	0,00	0,00	0,00	18,12	-15,50	310,05
$\Sigma_{z, \text{eff.}}$ [кПа]	0,00	0,00	0,00	18,12	-15,50	185,05
$\Sigma_{x, \text{tot.}}$ [кПа]	0,00	0,00	1,44	18,12	-15,50	248,37
$\Sigma_{x, \text{eff.}}$ [кПа]	0,00	0,00	1,44	18,12	-15,50	123,37
$\tau_{xy}$ [кПа]	1,94	-12,44	0,00	-16,67	-11,60	0,00

### Strain (extremes)

	Location		Min	Location		Max
	x [м]	z [м]		x [м]	z [м]	
Epsilon <sub>eq.</sub> [%]	18,12	-15,50	-2,22	0,00	0,00	-0,03
Epsilon <sub>eq., pl.</sub> [%]	0,00	-0,56	0,00	0,00	-0,56	0,00





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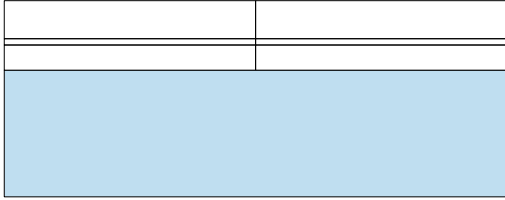

**Pore pressures (extremes)**

	Location		Max
	x [m]	z [m]	
Pore pressure u [кПа]	-0,04	-15,50	125,00

**Исход.данные (Этап проект 2)**

**Assignment and activation**

№	Region	Active / inactive	Assigned soil						
1	<table border="1" style="width: 100%; height: 80px;"> <tr><td style="width: 30%;"></td><td style="width: 70%;"></td></tr> <tr><td style="width: 30%;"></td><td style="width: 70%;"></td></tr> <tr><td style="width: 30%;"></td><td style="width: 70%;"></td></tr> </table>							Inactive	
2	<table border="1" style="width: 100%; height: 80px;"> <tr><td style="width: 30%;"></td><td style="width: 70%;"></td></tr> <tr><td style="width: 30%;"></td><td style="width: 70%;"></td></tr> <tr><td style="width: 30%;"></td><td style="width: 70%;"></td></tr> </table>							Active	S4 
3	<table border="1" style="width: 100%; height: 80px;"> <tr><td style="width: 30%;"></td><td style="width: 70%;"></td></tr> <tr><td style="width: 30%;"></td><td style="width: 70%;"></td></tr> <tr><td style="width: 30%;"></td><td style="width: 70%;"></td></tr> </table>							Inactive	
4	<table border="1" style="width: 100%; height: 80px;"> <tr><td style="width: 30%;"></td><td style="width: 70%;"></td></tr> <tr><td style="width: 30%;"></td><td style="width: 70%;"></td></tr> <tr><td style="width: 30%;"></td><td style="width: 70%;"></td></tr> </table>							Active	Тшнда F6, konzistence tuhб 
5	<table border="1" style="width: 100%; height: 80px;"> <tr><td style="width: 30%;"></td><td style="width: 70%;"></td></tr> <tr><td style="width: 30%;"></td><td style="width: 70%;"></td></tr> <tr><td style="width: 30%;"></td><td style="width: 70%;"></td></tr> </table>							Active	Тшнда F6, konzistence tuhб 
6	<table border="1" style="width: 100%; height: 80px;"> <tr><td style="width: 30%;"></td><td style="width: 70%;"></td></tr> <tr><td style="width: 30%;"></td><td style="width: 70%;"></td></tr> <tr><td style="width: 30%;"></td><td style="width: 70%;"></td></tr> </table>							Active	Тшнда F6, konzistence tuhб 

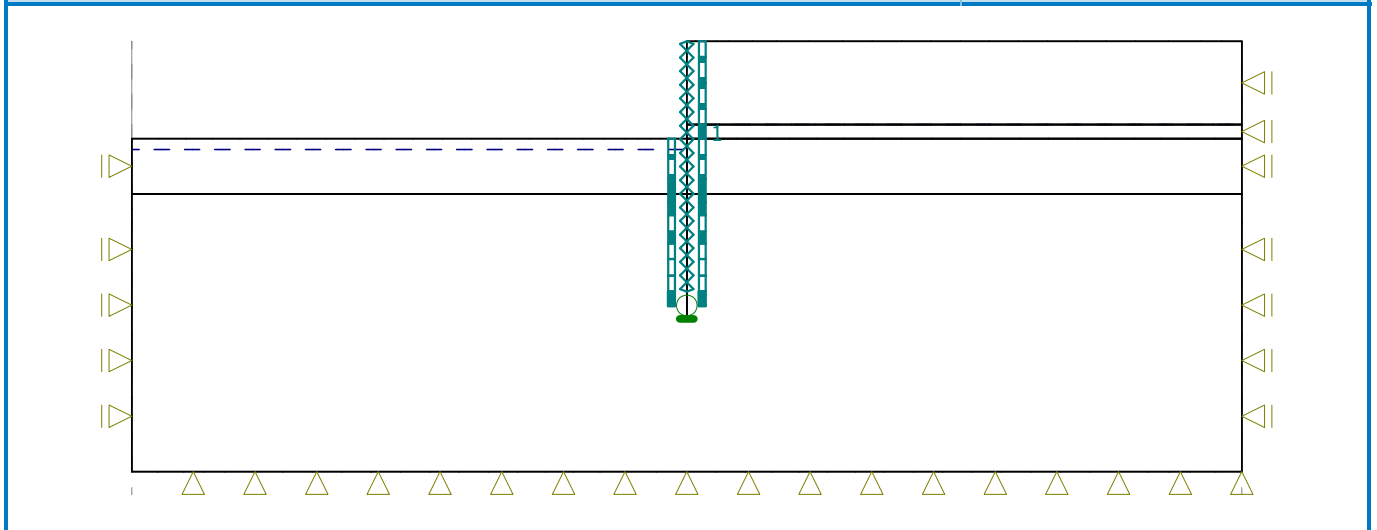
№	Region	Active / inactive	Assigned soil
7		Active	Тшнда F6, konzistence tuh6 

### Beams

№	Beam		Location	Support [м]		Include self weight	Cross-section	Material	Contacts	
	new	modified		Start pt.	End pt.				left	right
1	Да		Free line No. 1	0,500		Да	1,00 (b) x 0,50 (h) м	В 20	Контакт раённ земіна	Контакт раённ земіна

Имя : Балки

Этап : 2



### Line supports

№	Line support		Location	Support	
	new	modified		Direction X	Direction Z
A1	Да		Mesh line No. 15	fixed	free
A2	Да		Mesh line No. 13	fixed	free
A3	Да		Mesh line No. 17	fixed	free
A4	Да		Mesh line No. 12	fixed	free
A5	Да		Mesh line No. 8	fixed	free
A6	Да		Mesh line No. 2	fixed	free
A7	Да		Mesh line No. 16	fixed	fixed

A1 up to A7 - automatically generated line supports along model edges

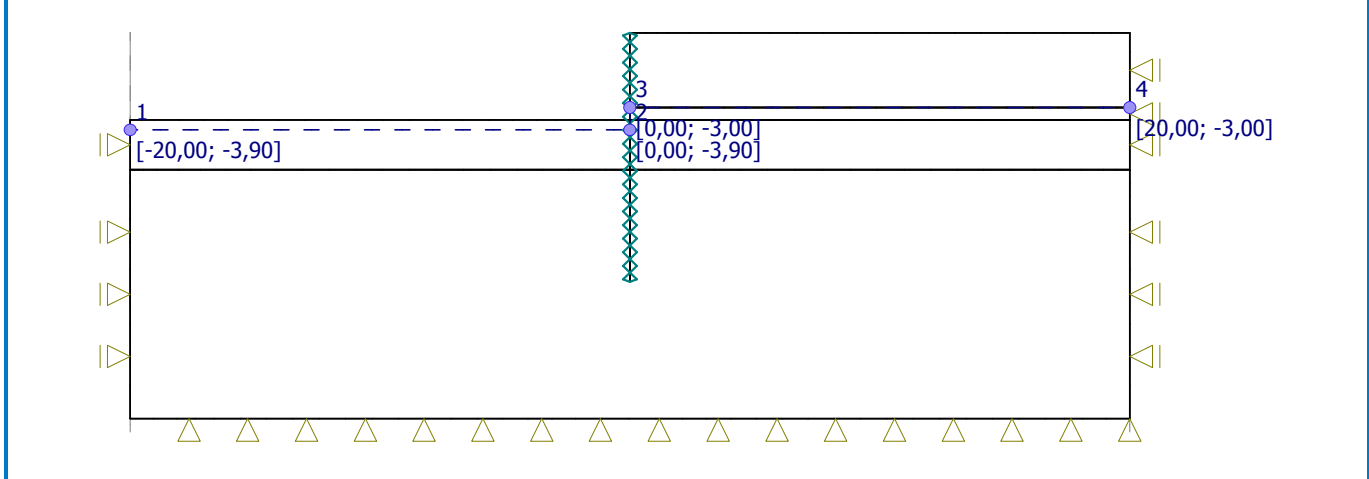
### Вода

Тип воды : У.Г.В.



№	Располож.У.Г.В.	Координаты точек У.Г.В. [м]					
		x	z	x	z	x	z
1		-20,00	-3,90	0,00	-3,90	0,00	-3,00
		20,00	-3,00				

Имя : Вода Этап : 2



### Analysis setting

#### General

Method : Newton - Raphson  
Stiffness matrix change : after each iteration  
Max. number of iterations for one calc. step : 100  
Initial calculation step : 0,25  
Displacement error : 0,0100  
Imbalanced forces error : 0,0100  
Energy error : 0,0100  
Respect material interfaces : NO

#### Newton - Raphson

Relaxation factor : 2  
Max. number of relaxations for one calc. step : 2  
Min. number of iterations for one calc. step : 1

#### Line search

Solution method : iterate no  
Line search limit - minimum : 0,100  
Line search limit - maximum : 1,000

#### Plasticity

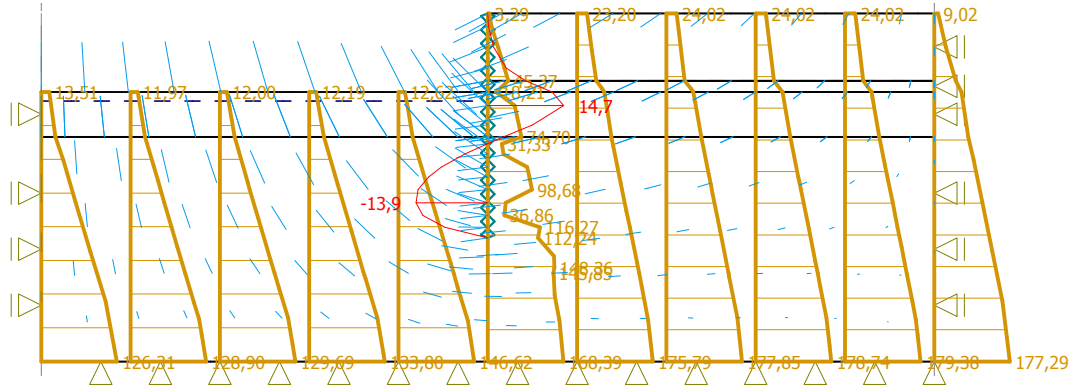
Return mapping error : 0,00100  
Max. number of iterations for one plast. step : 20

### Результаты (Эт.проект. 2)

**Stress analysis was successfully completed.**

Analysis setting : **standard**  
Attained loading = 100,00 %

Results : суммар.; variable :  $\text{Sigma}_{z, \text{eff.}}$ ; range :  $\langle 0,00; 181,98 \rangle$  кПа  
 М [кНм/м]



## Extremes

### Displacements (extremes)

	Location		Min	Location		Max
	x [m]	z [m]		x [m]	z [m]	
Displacements x [m]	20,00	0,00	0,0	0,00	0,00	69,5
Displacements z [m]	-9,86	-3,50	-84,6	1,52	0,00	31,3

### Stress (extremes)

	Location		Min	Location		Max
	x [m]	z [m]		x [m]	z [m]	
$\text{Sigma}_{z, \text{tot.}}$ [кПа]	0,00	0,00	0,00	18,12	-15,50	306,98
$\text{Sigma}_{z, \text{eff.}}$ [кПа]	0,00	0,00	0,00	18,12	-15,50	181,98
$\text{Sigma}_{x, \text{tot.}}$ [кПа]	20,00	0,00	-2,27	18,12	-15,50	245,33
$\text{Sigma}_{x, \text{eff.}}$ [кПа]	20,00	0,00	-2,27	18,12	-15,50	120,33
$\text{Tau}_{xy}$ [кПа]	0,00	-9,53	-2,70	-0,89	-10,55	23,76

### Strain (extremes)

	Location		Min	Location		Max
	x [m]	z [m]		x [m]	z [m]	
Epsilon <sub>eq.</sub> [%]	-0,19	-10,85	-2,55	0,00	0,00	-0,05
Epsilon <sub>eq., pl.</sub> [%]	0,00	-2,44	-1,78	20,00	-3,50	0,00

### Pore pressures (extremes)

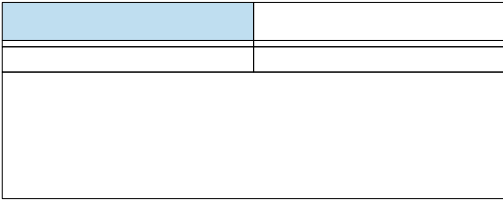
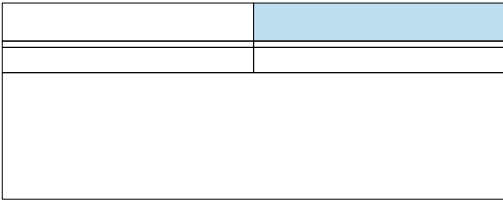

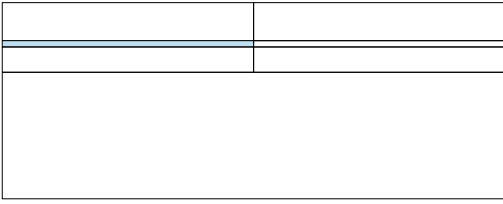
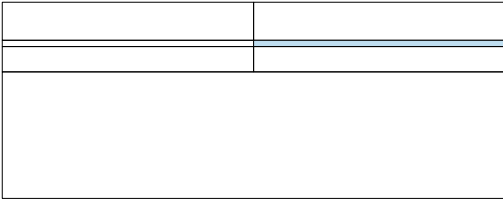

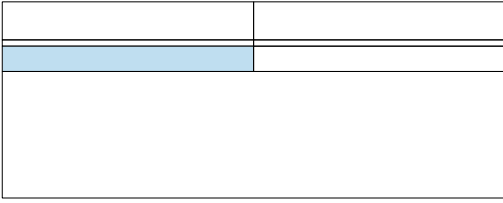
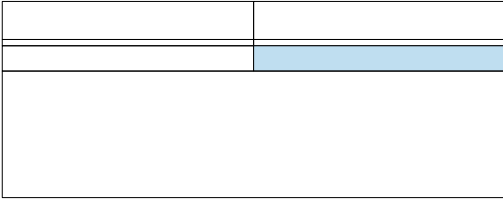

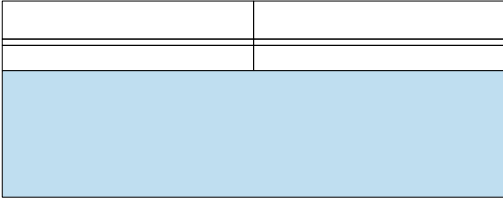

	Location		Max
	x [m]	z [m]	
Pore pressure u [кПа]	2,11	-15,50	125,00

### Distributions on beams (extremes)

	Location		Min	Location		Max
	x [m]	z [m]		x [m]	z [m]	
N [кН/м]	0,00	-10,00	-110,1	0,00	0,00	-0,1
Q [кН/м]	0,00	-10,00	-20,4	0,00	-5,50	10,5
M [кНм/м]	0,00	-8,44	-13,9	0,00	-4,11	14,7

## Исход.данные (Этап проект 3)

### Assignment and activation

№	Region	Active / inactive	Assigned soil
1		Inactive	
2		Active	S4 
3		Inactive	
4		Active	Тшнда F6, konzistence tuhб 
5		Inactive	
6		Active	Тшнда F6, konzistence tuhб 
7		Active	Тшнда F6, konzistence tuhб 

### Beams

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№	Beam		Location	Support [м]		Include self weight	Cross-section	Material	Contacts	
	new	modified		Start pt.	End pt.				left	right
1	Нет	Нет	Free line No. 1	0,500		Да	without modification	without modification	Kontakt раћенн zemina	Kontakt раћенн zemina

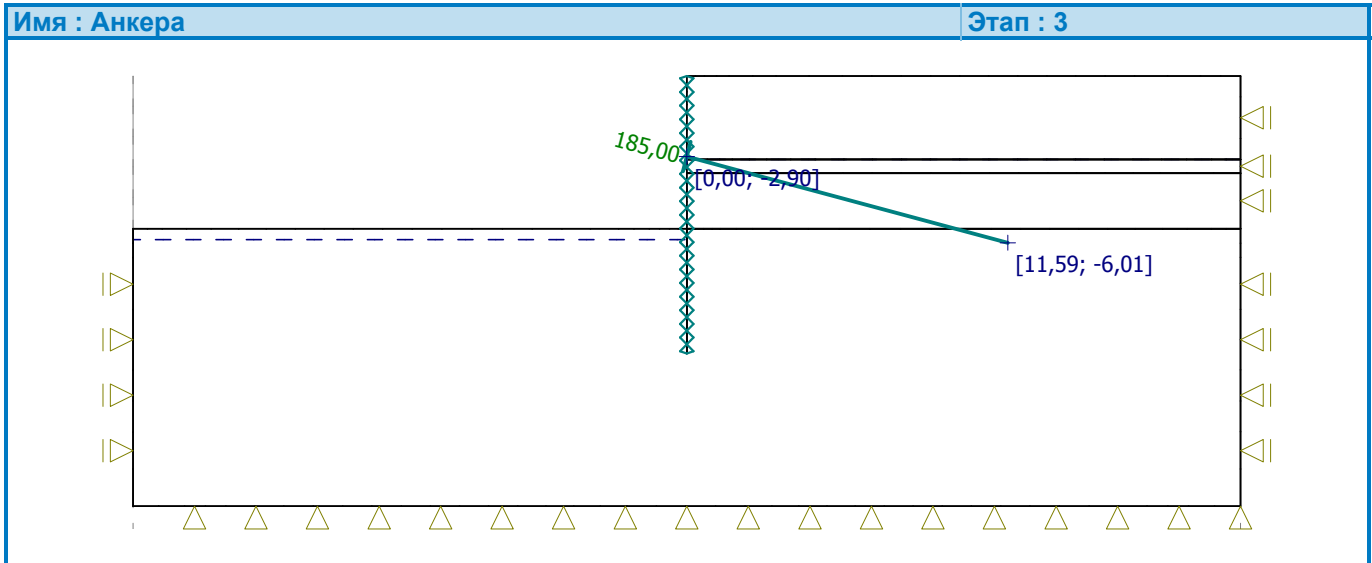
### Line supports

№	Line support		Location	Support	
	new	modified		Direction X	Direction Z
A1	Да		Mesh line No. 15	fixed	free
A2	Да		Mesh line No. 17	fixed	free
A3	Да		Mesh line No. 12	fixed	free
A4	Да		Mesh line No. 8	fixed	free
A5	Да		Mesh line No. 2	fixed	free
A6	Да		Mesh line No. 16	fixed	fixed

A1 up to A6 - automatically generated line supports along model edges

### Анкера

№	Анкер		Начало		Длина и наклон/координат		Шаг b [м]	Диаметр d [мм] / A [мм²]	Модуль упруг. E [МПа]	Пред.с.р. F <sub>c</sub> [кН]	Действие в сжатии	Усилие F [кН]
	новый	пол.натя	x [м]	z [м]	l [м] / α [°]	x [м] / z [м]						
1	Да		0,00	-2,90	l = 12,00	α = 15,00	1,00	d = 10,0	2100000,0	1E80	Нет	185,00



### Вода

Тип воды : У.Г.В.

№	Располож.У.Г.В.	Координаты точек У.Г.В. [м]					
		x	z	x	z	x	z
1		-20,00	-5,90	0,00	-5,90	0,00	-3,00
		20,00	-3,00				

### Analysis setting

### General

Method : Newton - Raphson  
 Stiffness matrix change : after each iteration  
 Max. number of iterations for one calc. step : 100  
 Initial calculation step : 0,25  
 Displacement error : 0,0100  
 Imbalanced forces error : 0,0100  
 Energy error : 0,0100  
 Respect material interfaces : NO

### Newton - Raphson

Relaxation factor : 2  
 Max. number of relaxations for one calc. step : 2  
 Min. number of iterations for one calc. step : 1

### Line search

Solution method : iterate no  
 Line search limit - minimum : 0,100  
 Line search limit - maximum : 1,000

### Plasticity

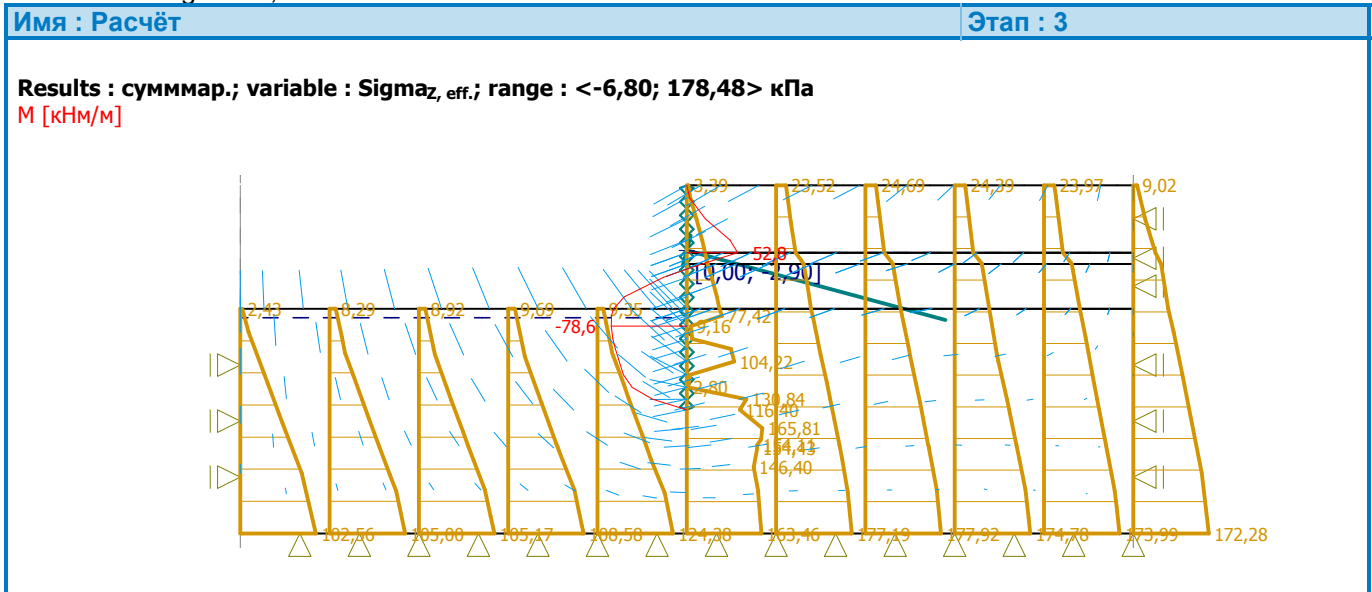
Return mapping error : 0,00100  
 Max. number of iterations for one plast. step : 20

## Результаты (Эт.проект. 3)

**Stress analysis was successfully completed.**

Analysis setting : **standard**

Attained loading = 100,00 %



### Extremes

#### Displacements (extremes)

	Location		Min	Location		Max
	x [м]	z [м]		x [м]	z [м]	
Displacements x [м]	20,00	0,00	0,0	0,00	0,00	97,4
Displacements z [м]	-6,66	-5,50	-105,8	1,52	0,00	51,3

#### Stress (extremes)

	Location		Min	Location		Max
	x [м]	z [м]		x [м]	z [м]	
$\Sigma_{\sigma z, tot.}$ [кПа]	-20,00	-5,50	0,00	6,08	-15,50	303,48

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	Location		Min	Location		Max
	x [m]	z [m]		x [m]	z [m]	
Sigma <sub>Z, eff.</sub> [кПа]	0,00	-9,53	-6,80	6,08	-15,50	178,48
Sigma <sub>X, tot.</sub> [кПа]	20,00	0,00	-2,12	18,12	-15,50	240,98
Sigma <sub>X, eff.</sub> [кПа]	20,00	0,00	-2,12	18,12	-15,50	115,98
Tau <sub>XY</sub> [кПа]	0,00	-9,53	-7,34	-0,68	-11,38	39,99

### Strain (extremes)

	Location		Min	Location		Max
	x [m]	z [m]		x [m]	z [m]	
Epsilon <sub>eq.</sub> [%]	0,00	-9,53	-8,09	0,63	0,00	-0,10
Epsilon <sub>eq., pl.</sub> [%]	0,00	-9,53	-7,36	7,75	-3,50	0,00

### Pore pressures (extremes)

	Location		Max
	x [m]	z [m]	
Pore pressure u [кПа]	2,11	-15,50	125,00

### Distributions on beams (extremes)

	Location		Min	Location		Max
	x [m]	z [m]		x [m]	z [m]	
N [кН/м]	0,00	-10,00	-147,9	0,00	0,00	-0,1
Q [кН/м]	0,00	-10,00	-89,5	0,00	-3,50	71,0
M [кНм/м]	0,00	-6,27	-78,6	0,00	-3,00	52,8