

adit is progressively excavated and supported across the mainline tunnel less relaxation has occurred at the mainline tunnel than calculated by the plane strain condition. To address this a ground relaxation of only 25% has been adopted for the Kingsgrove north and south tunnel intersections. A sensitivity case with 50% relaxation has also been carried out to check that higher than expected ground relaxation will not compromise the stability of the excavation.

### 1.4.3 Numerical models

A summary of each analysis model, support type and ground type is presented in Table 18. General arrangements of each numerical model are also presented in Figure 1 to Figure 10.

Table 18 Model summary

Design section	Ch	Support type	Ground type	In situ stress condition	Figure ID
EB-1	2080 M110	M2-HS-TYPE E-WP1-S	GT-H-4	Intermediate	Figure 1
EB-1				Low	
EB-2	2090 M110	M2-HS-TYPE E-KGN	GT-H-4	Intermediate	Figure 2
EB-2				Low	
EB-3	2120 M110	M2-HS-TYPE E-WP1	GT-H-4	Typical	Figure 3
EB-3				Intermediate	
EB-3	2120 M110	M2-HS-TYPE D-LEP	GT-H-4	Typical	Figure 4
EB-3				Intermediate	
WB-1	2180 M120	M2-HS-TYPE E-WP3	Refer to Figure 5	Intermediate	Figure 5
WB-1				Low	
WB-2	2240 M120	M2-HS-TYPE E-WP3-LEP	Refer to Figure 6	Intermediate	Figure 6
WB-2				Low	
WB-3	2320 M120	M2-HS-TYPE E-WP3-LEP	Refer to Figure 7	Intermediate	Figure 7
WB-3				Low	
WB-4	2418 M120	M2-HS-TYPE E-WP2-LEP-S	GT-H-4	Intermediate	Figure 8
WB-4				Low	
WB-5	2445 M120	M2-HS-TYPE E-WP1-LEP	GT-H-4	Typical	Figure 9
WB-5				Intermediate	
WB-6	2500 M120	M2-HS-TYPE D	GT-H-4	Typical	Figure 10
WB-6				Intermediate	

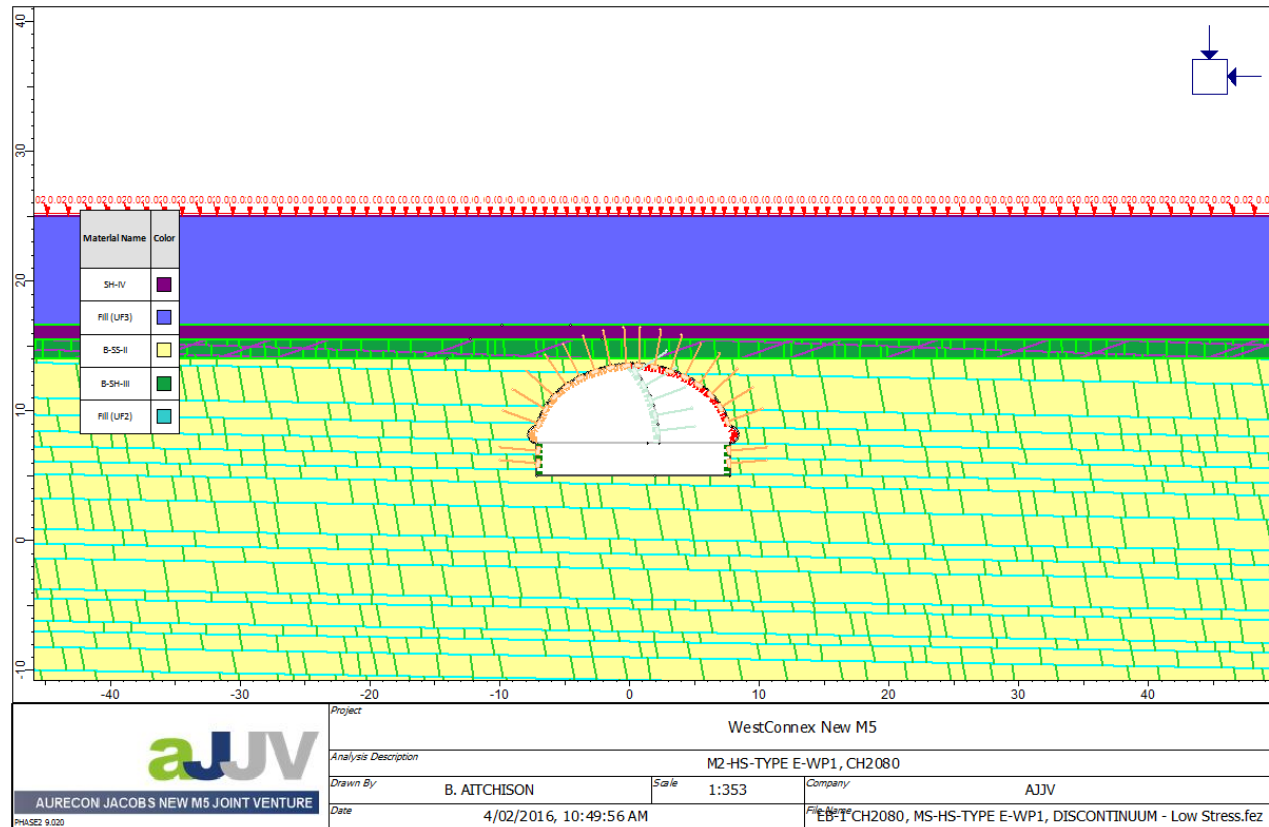


Figure 1 EB-1 CH2080 M2-HS-TYPE E-WP1-S

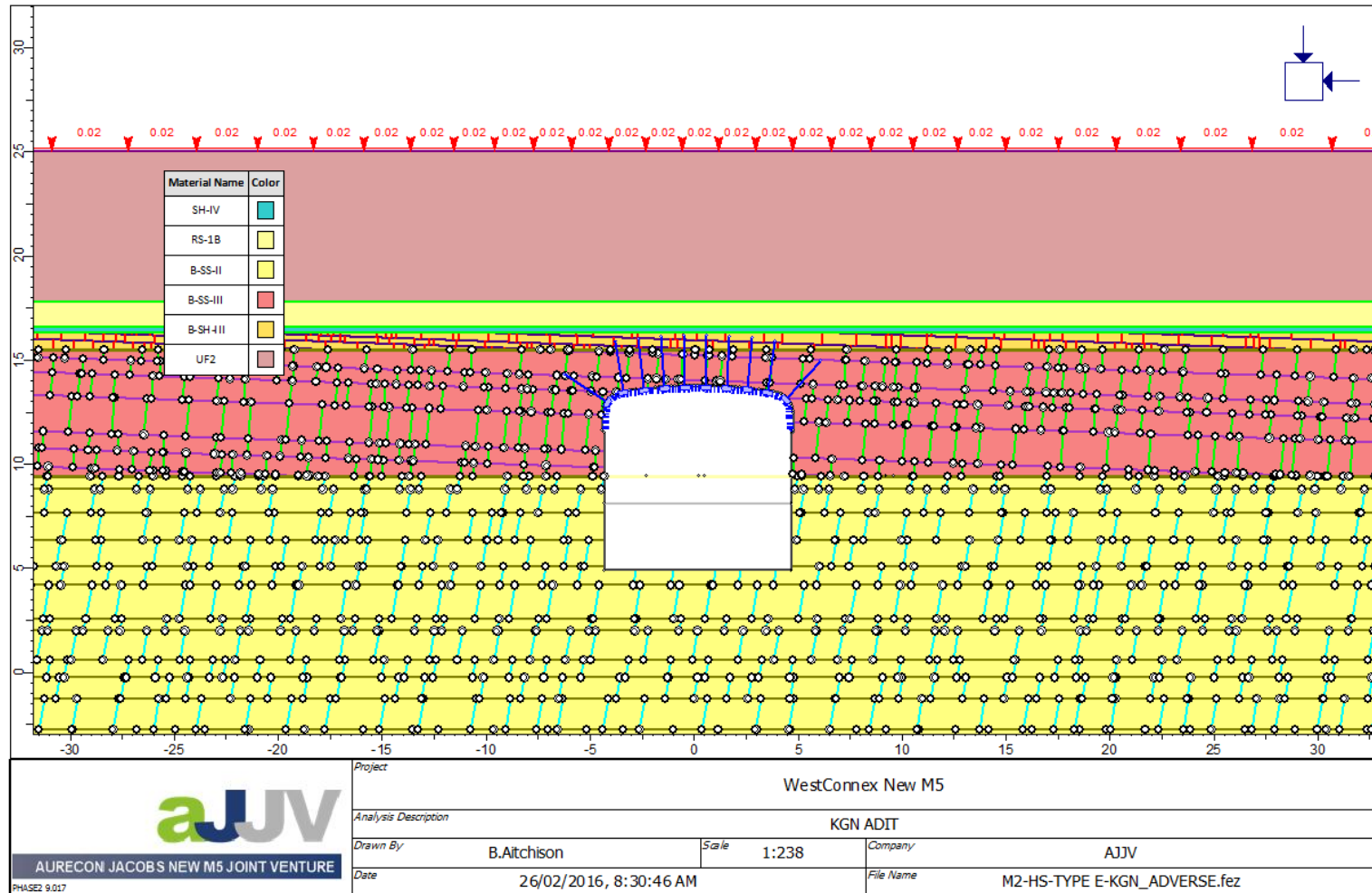


Figure 2 EB-2 CH2090 M2-HS-TYPE E-KGN

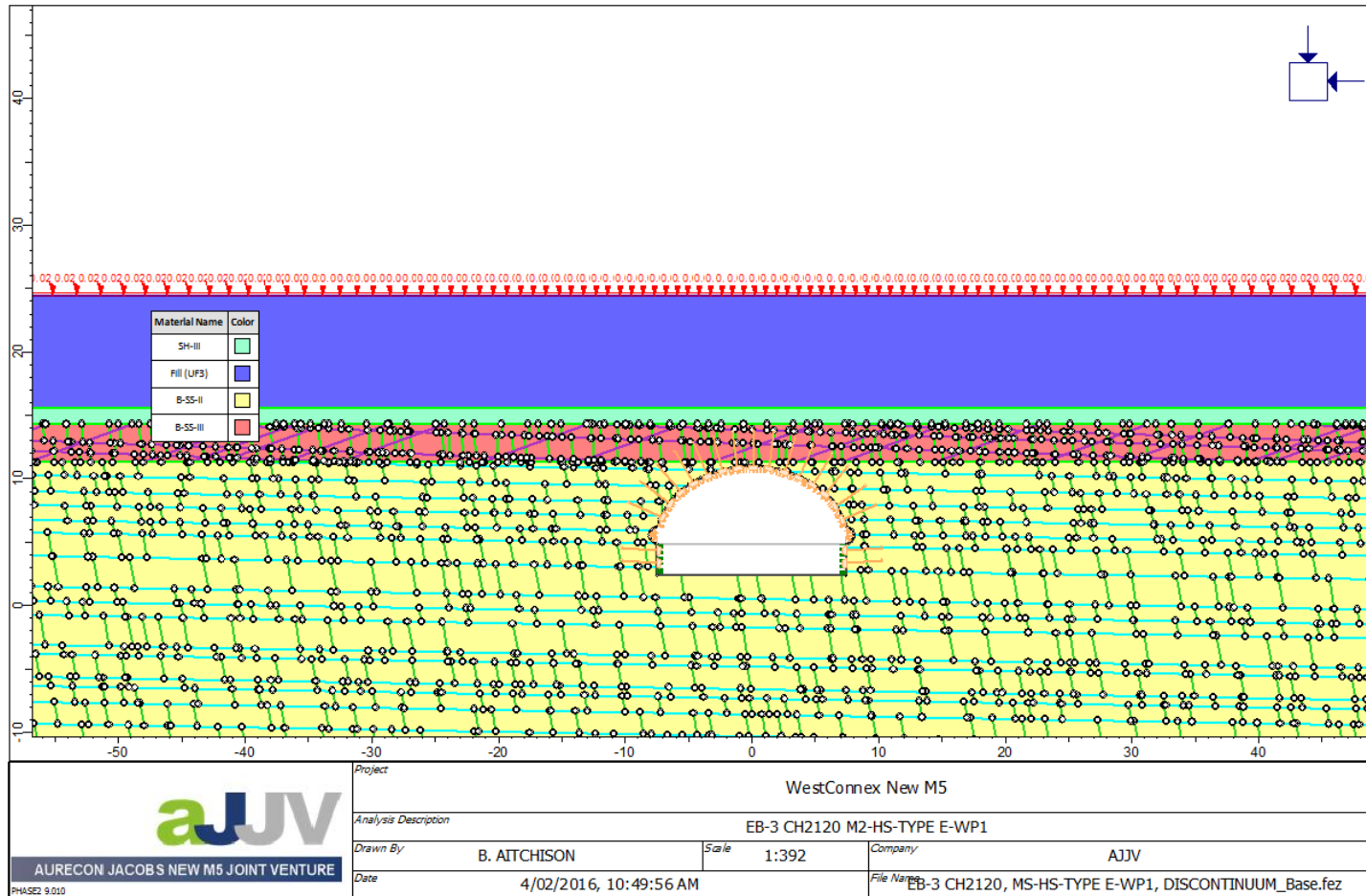


Figure 3 EB-3 CH2120 M2-HS-TYPE E-WP1

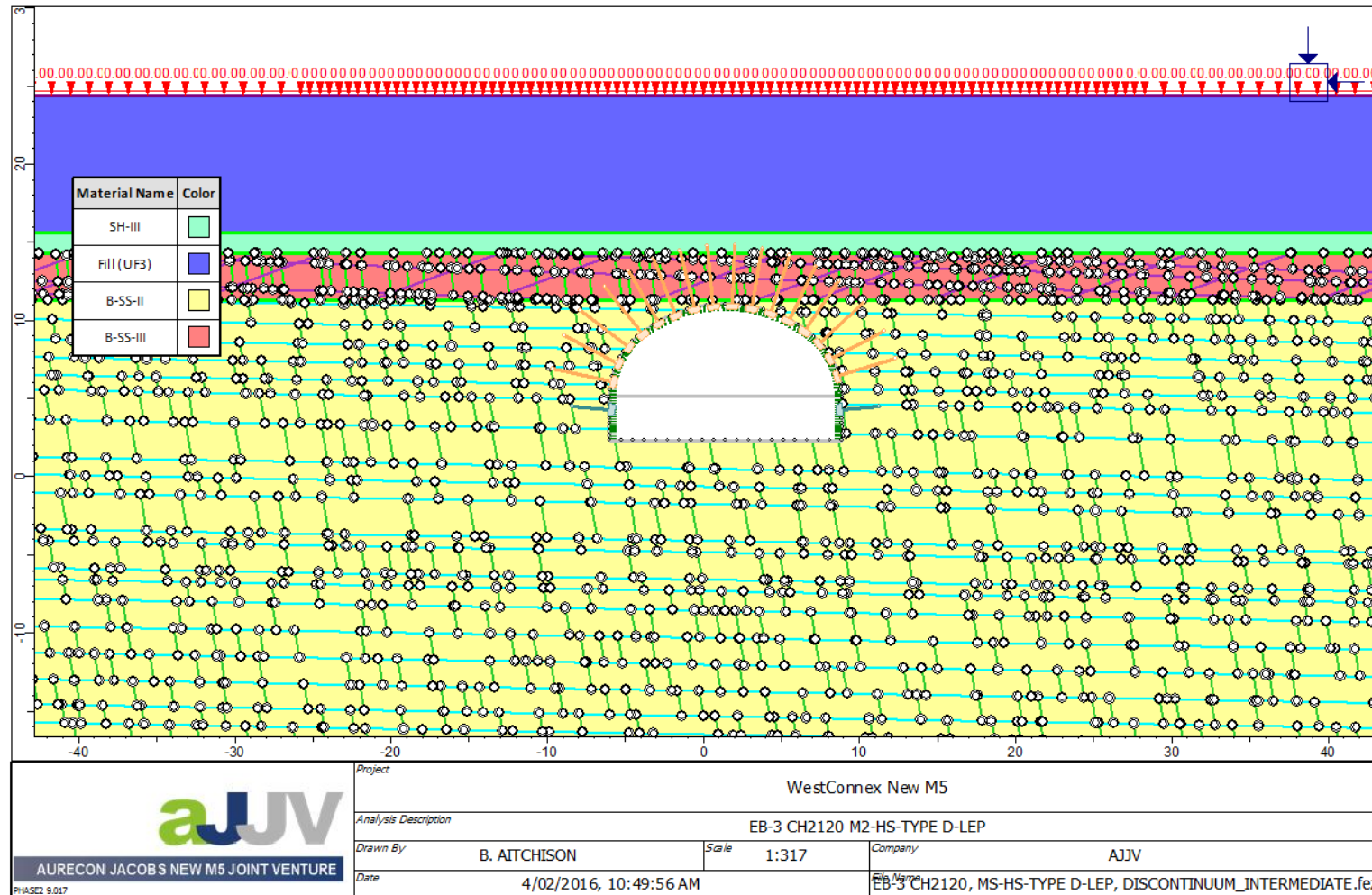


Figure 4 EB-3 CH2120 M2-HS-TYPE D-LEP

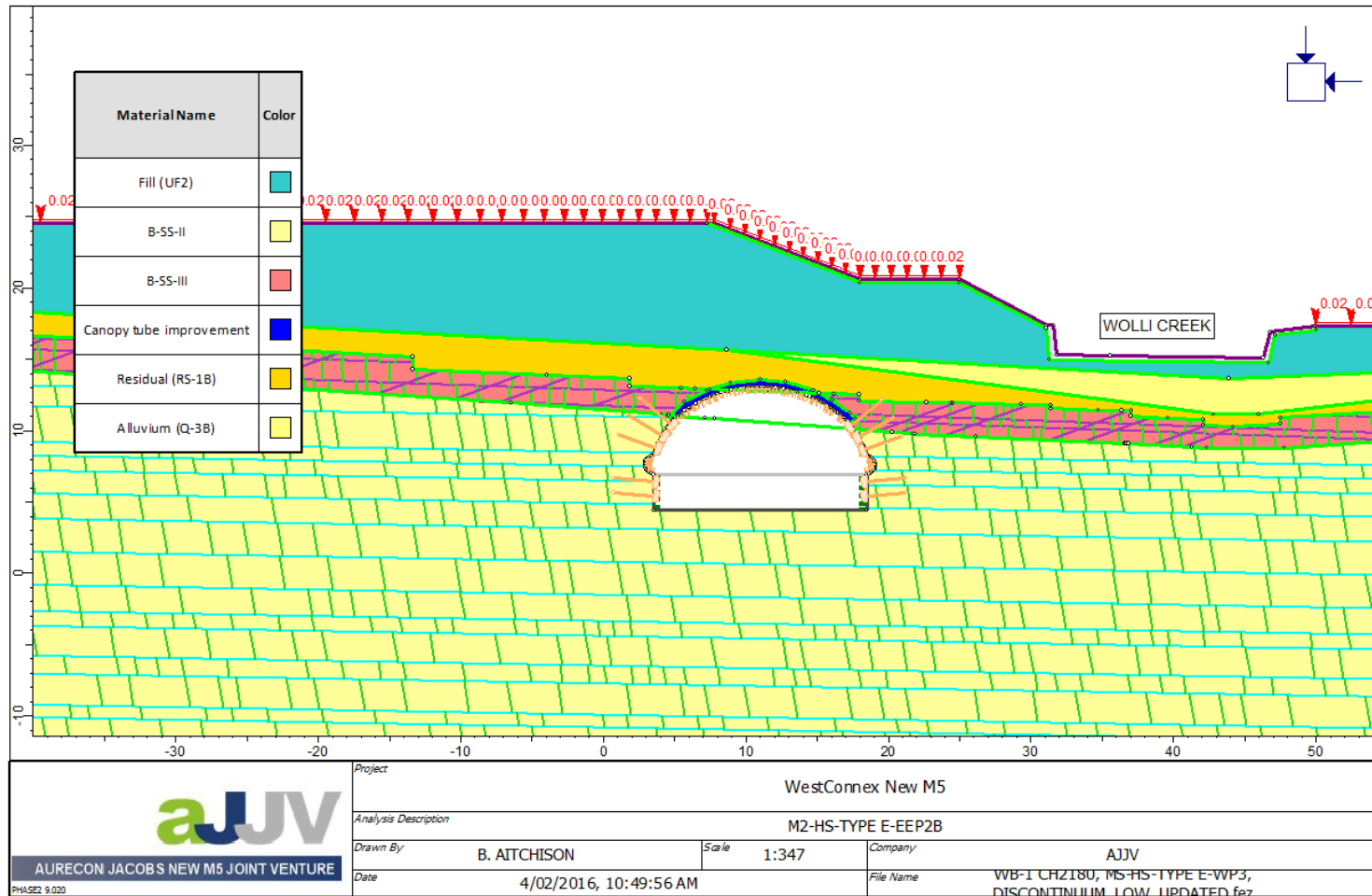


Figure 5 WB-1 CH2180 M2-HS-TYPE E-WP3

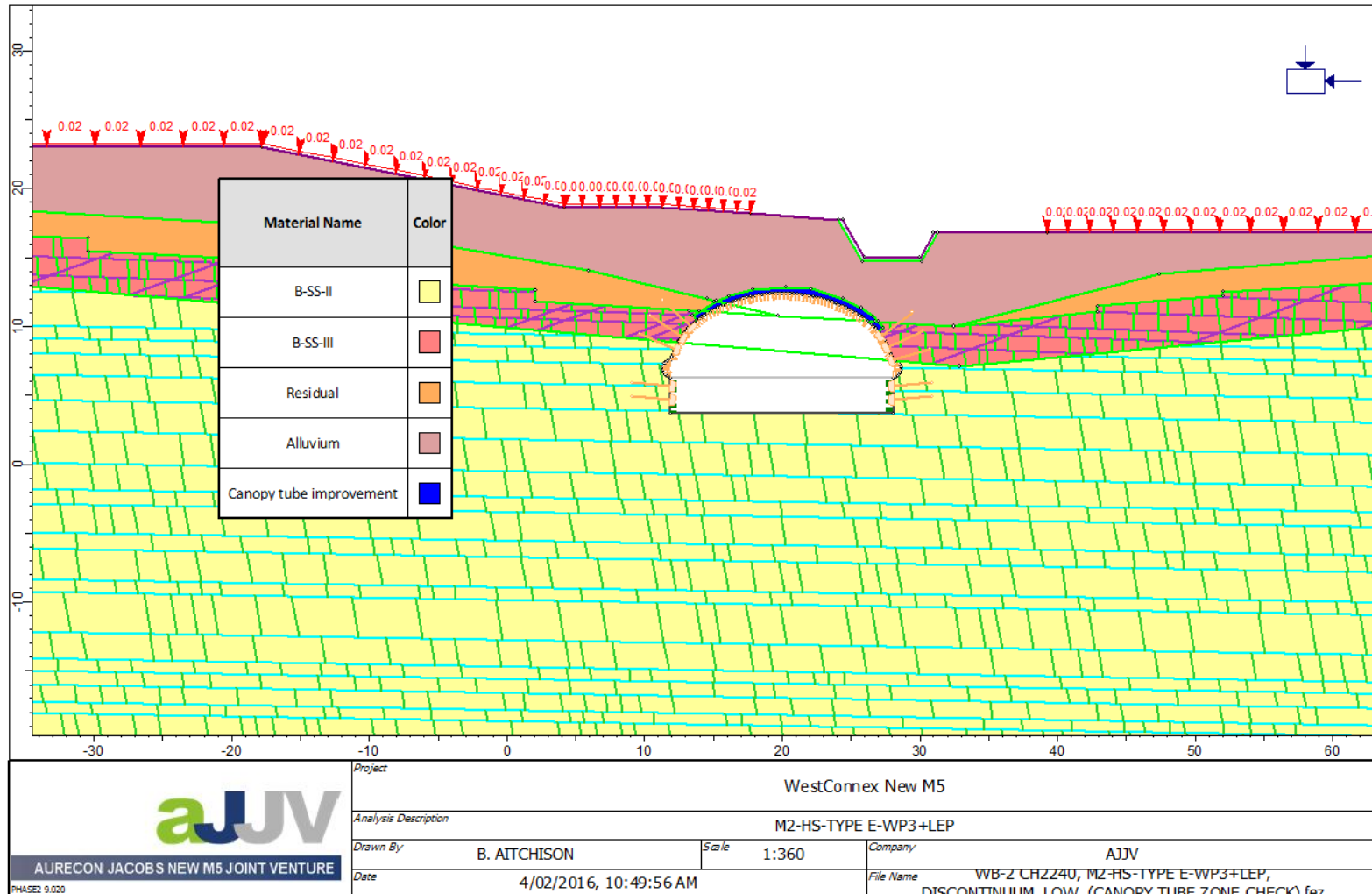


Figure 6 WB-2 CH2240 M2-HS-TYPE E-WP3-LEP



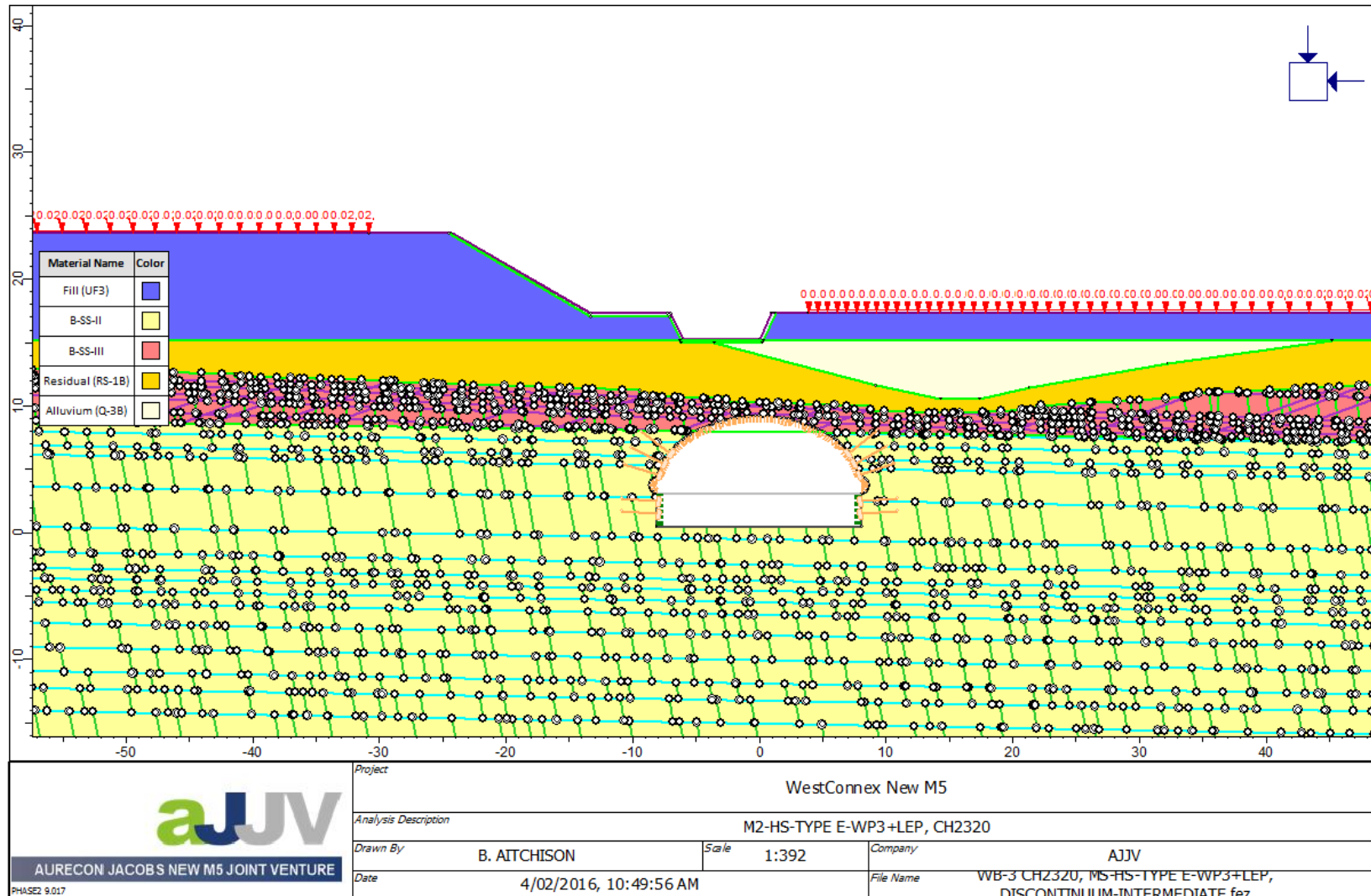


Figure 7 WB-3 CH2320 M2-HS-TYPE E-WP3-LEP



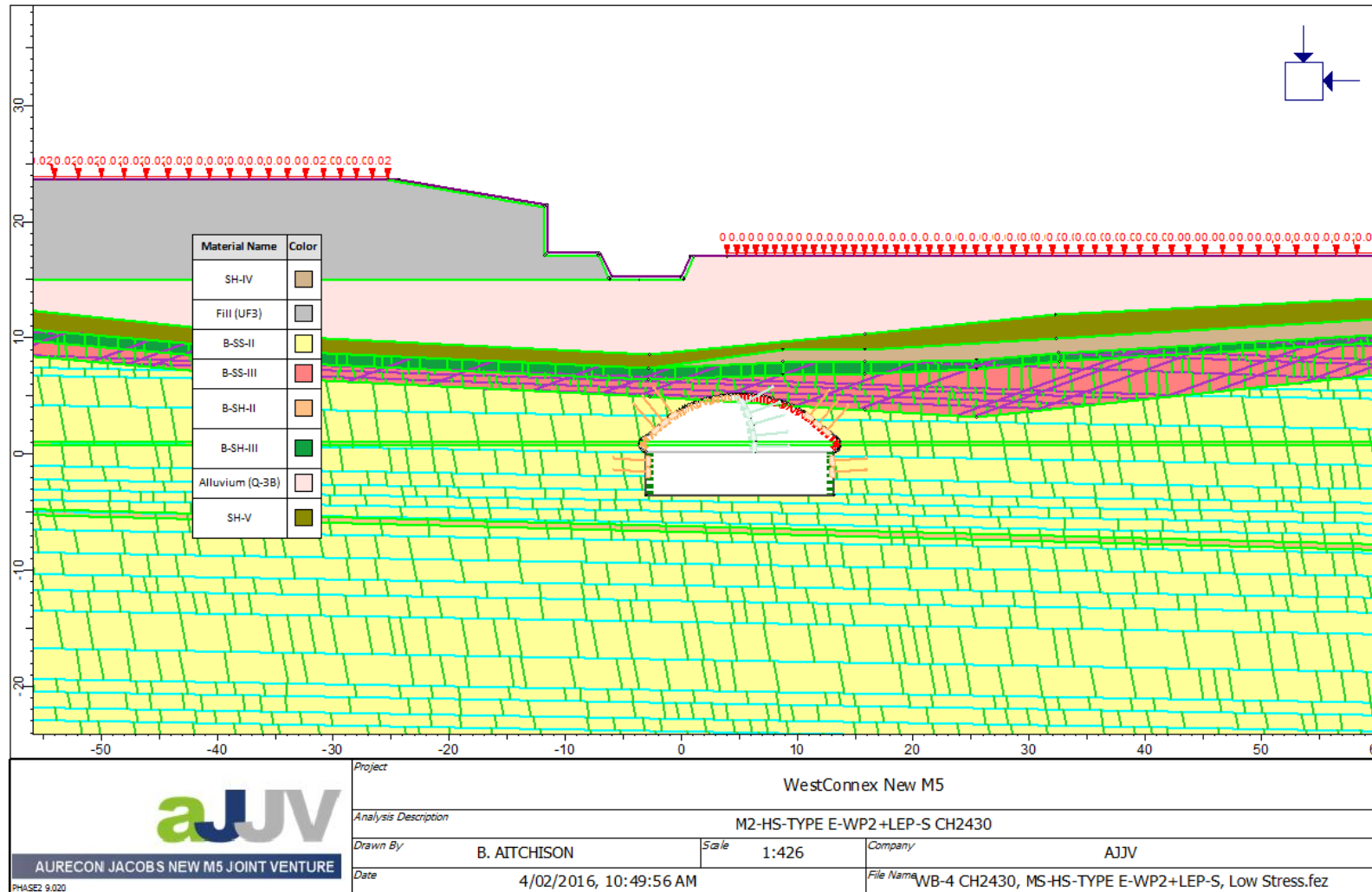


Figure 8 WB-4 CH2430 M2-HS-TYPE E-WP2+LEP-S

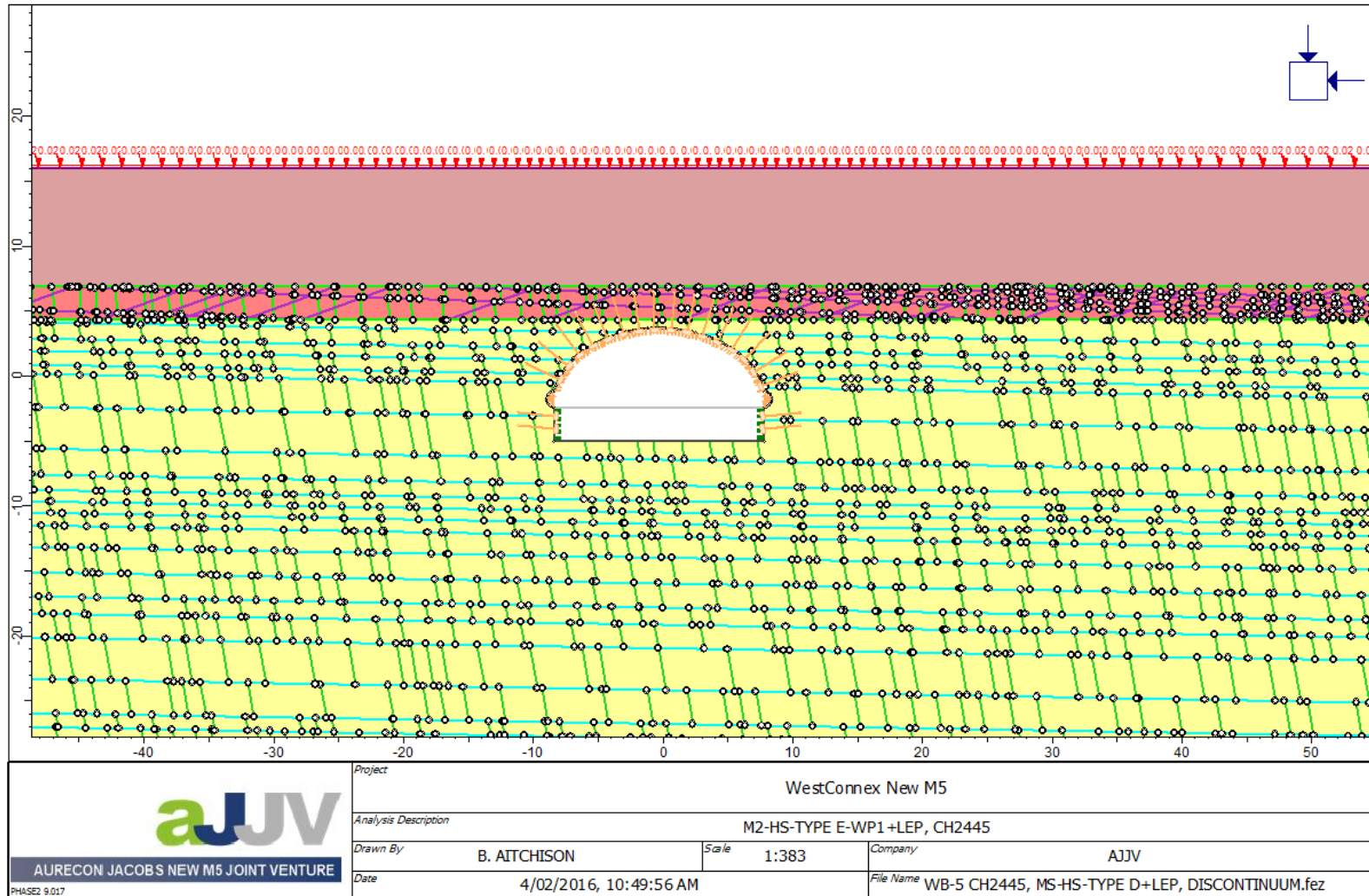


Figure 9 WB-5 CH2445 M2-HS-TYPE E-WP1-LEP

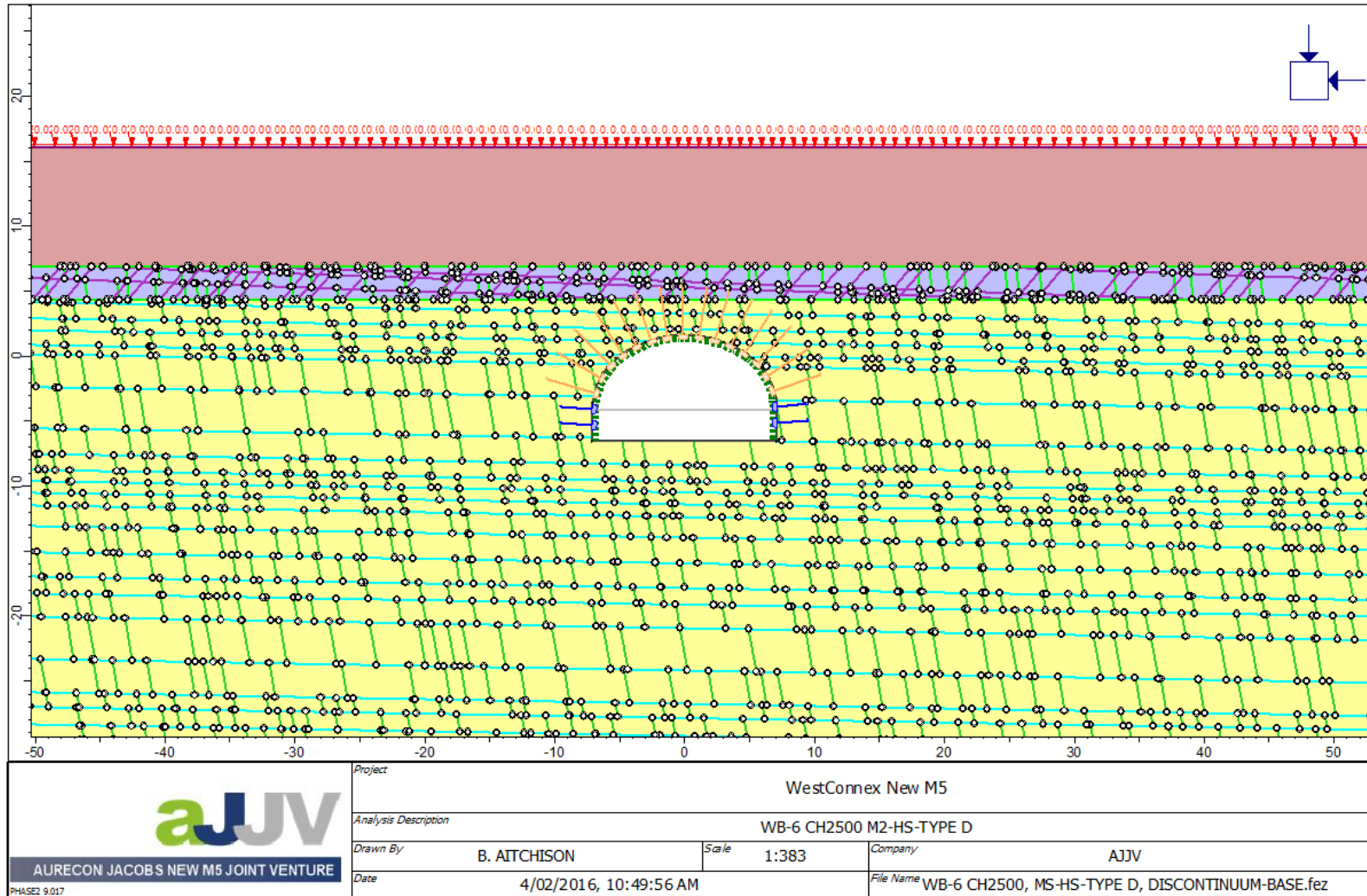


Figure 10 WB-6 CH2500 M2-HS-TYPE D

## 1.5 Results

Analysis results from the modelling are verified by reviewing the models in detail considering the tunnel behaviour and support design actions. In general, for each design section two models are ran which consider the two stress conditions listed in Table 10 and Table 11 depending on the design section being evaluated.

### Shotcrete and rock bolts

The shotcrete lining ULS design actions (axial force, bending moment and shear force) are extracted from the model and compared to the capacity curves (M-N and V-N diagrams). Results which fall within the capacity curves are deemed satisfactory.

The rock bolt axial forces are extracted from the model and compared to the bolt capacity diagram which considers the development of capacity along the bolt length.

### Ground behaviour

The behaviour of the ground is assessed by considering the stresses, displacements, surface settlements and joint movements.

#### 1.5.1 Ground displacement

Model extracts which show total displacement contours for each design section are presented in Figure 11 to Figure 38. Maximum vertical and horizontal displacements are tabulated in Table 19.

Table 19 Summary of maximum vertical displacement of crown and maximum horizontal displacement of side wall

Section ID	Description	Detail	Maximum vertical displacement at crown [mm]	Maximum horizontal displacement at side wall [mm]
EB-1	EB-1 CH 2080 M2-HS-TYPE E-WP1-S 50% INTERMEDIATE STRESS	AT COMPLETION OF HEADING 1	5	4
		AT COMPLETION OF BOTH HEADINGS	13	6
	EB-1 CH 2080 M2-HS-TYPE E-WP1-S 50% LOW STRESS	AT COMPLETION OF HEADING 1	5	1
		AT COMPLETION OF BOTH HEADINGS	15	1
	EB-1 CH 2080 M2-HS-TYPE E-WP1-S 25% INTERMEDIATE STRESS	AT COMPLETION OF HEADING 1	4	4
		AT COMPLETION OF BOTH HEADINGS	13	5
EB-2	EB-2 CH2090 M2-HS-TYPE E-KGN 50% INTERMEDIATE STRESS		40	4

Section ID	Description	Detail	Maximum vertical displacement at crown [mm]	Maximum horizontal displacement at side wall [mm]
	EB-2 CH2090 M2-HS-TYPE E-KGN 50% LOW STRESS		40	2
EB-3	EB-3 CH 2120 M2-HS-TYPE E-WP1 50% INTERMEDIATE STRESS		8	5
	EB-3 CH 2120 M2-HS-TYPE E-WP1 50% TYPICAL STRESS		8	5
	EB-3 CH 2120 M2-HS-TYPE D-LEP 50% INTERMEDIATE STRESS		10	5
	EB-3 CH 2120 M2-HS-TYPE D-LEP 50% TYPICAL STRESS		15	11
WB-1	WB-1 CH 2180 M2-HS-TYPE E-WP3 50% INTERMEDIATE STRESS		10	4
	WB-1 CH 2180 M2-HS-TYPE E-WP3 50% LOW STRESS		14	1
WB-2	WB-2 CH 2240 M2-HS-TYPE E-WP3-LEP 50% INTERMEDIATE STRESS		18	5
	WB-2 CH 2240 M2-HS-TYPE E-WP3-LEP 50% LOW STRESS		22	1
WB-3	WB-3 CH 2320 M2-HS-TYPE E-WP3-LEP 50% INTERMEDIATE STRESS		16	5
	WB-3 CH 2320 M2-HS-TYPE E-WP3-LEP 50% LOW STRESS		19	2
WB-4	WB-4 CH 2418 M2-HS-TYPE E-WP2-LEP-S 50% INTERMEDIATE STRESS	AT COMPLETION OF HEADING 1	6	3
		AT COMPLETION OF BOTH HEADINGS	45	6
	WB-4 CH 2418 M2-HS-TYPE E-WP2-LEP-S 50% LOW STRESS	AT COMPLETION OF HEADING 1	10	2
		AT COMPLETION OF BOTH HEADINGS	50	2
	WB-4 CH 2418 M2-HS-TYPE E-WP2-LEP-S 25% INTERMEDIATE STRESS	AT COMPLETION OF HEADING 1	5	3
		AT COMPLETION OF BOTH HEADINGS	45	6
WB-5	WB-5 CH 2445 M2-HS-TYPE E-WP1-LEP 50% TYPICAL STRESS		11	8

Section ID	Description	Detail	Maximum vertical displacement at crown [mm]	Maximum horizontal displacement at side wall [mm]
	WB-5 CH 2445 M2-HS-TYPE E-WP1-LEP 50% INTERMEDIATE STRESS		11	5
WB-6	WB-6 CH 2500 M2-HS-TYPE D 50% TYPICAL STRESS		7	9

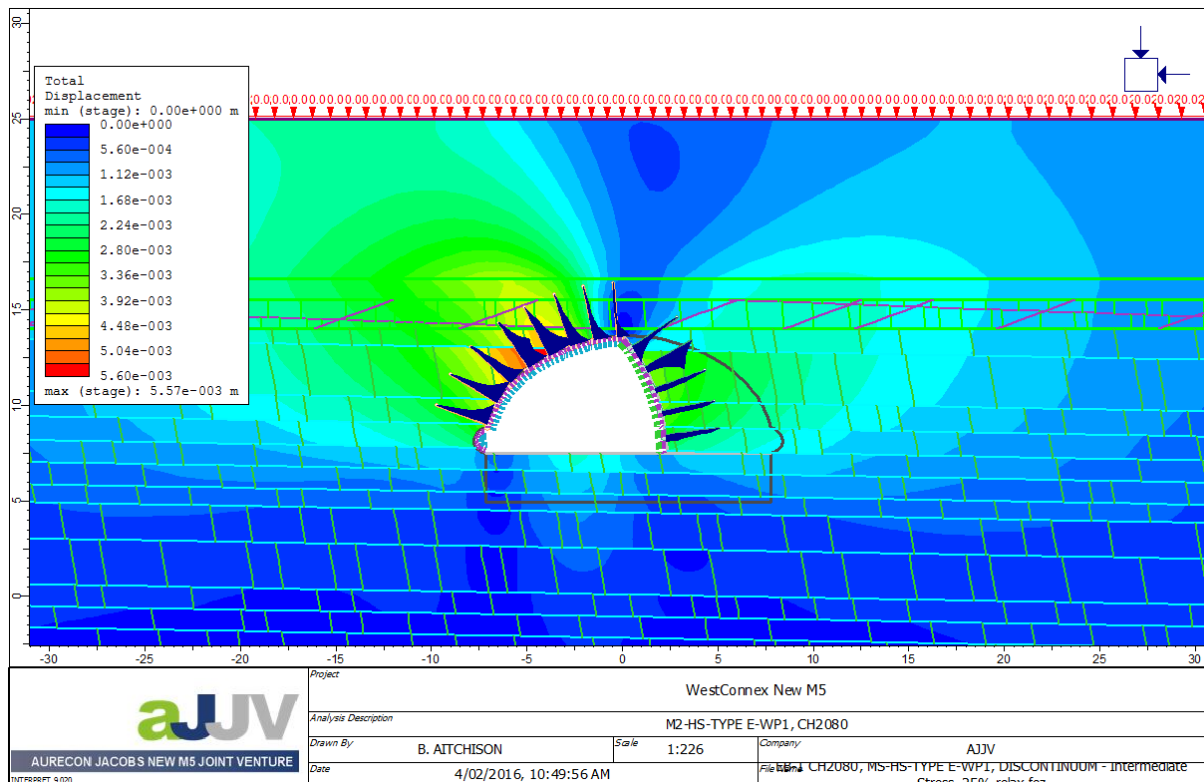


Figure 11 EB-1 CH2080 M2-HS-TYPE E-WP1-S – 25% RELAX – INTERMEDIATE STRESS - AT COMPLETION OF HEADING 1

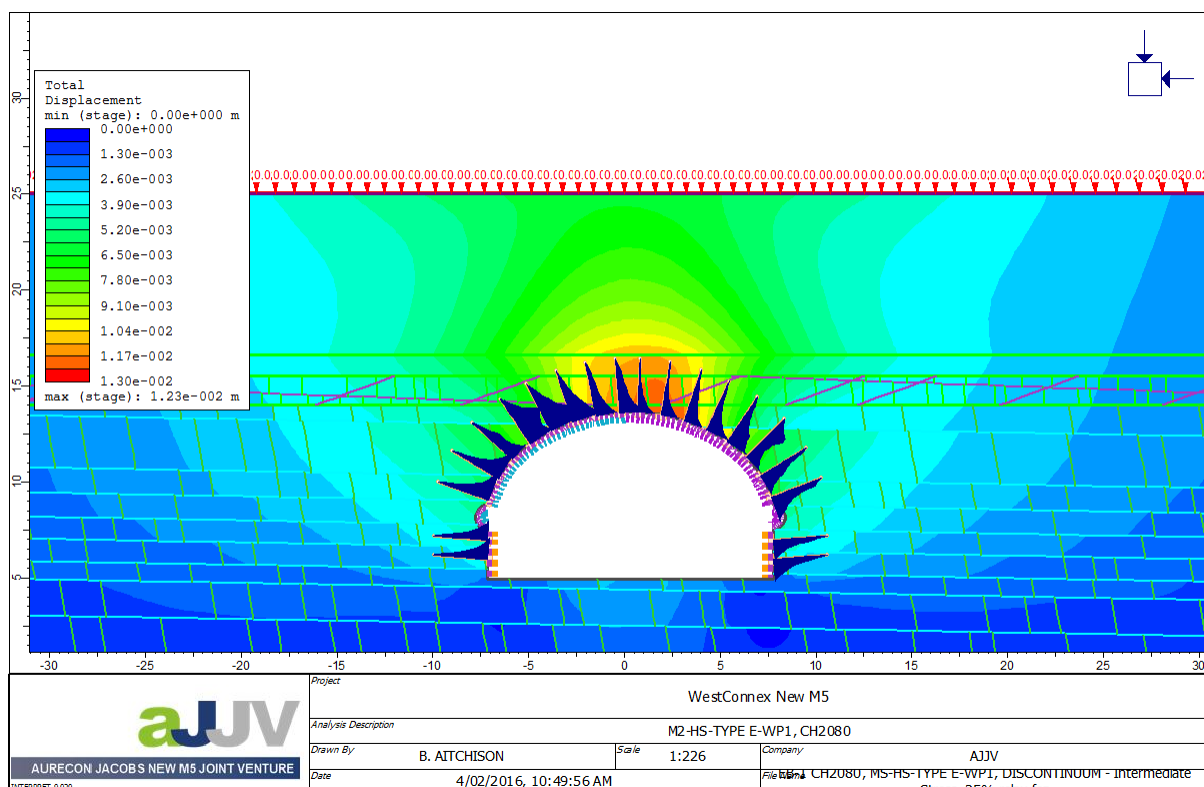


Figure 12 EB-1 CH2080 M2-HS-TYPE E-WP1-S – 25% RELAX – INTERMEDIATE STRESS - AT COMPLETION OF BOTH HEADINGS



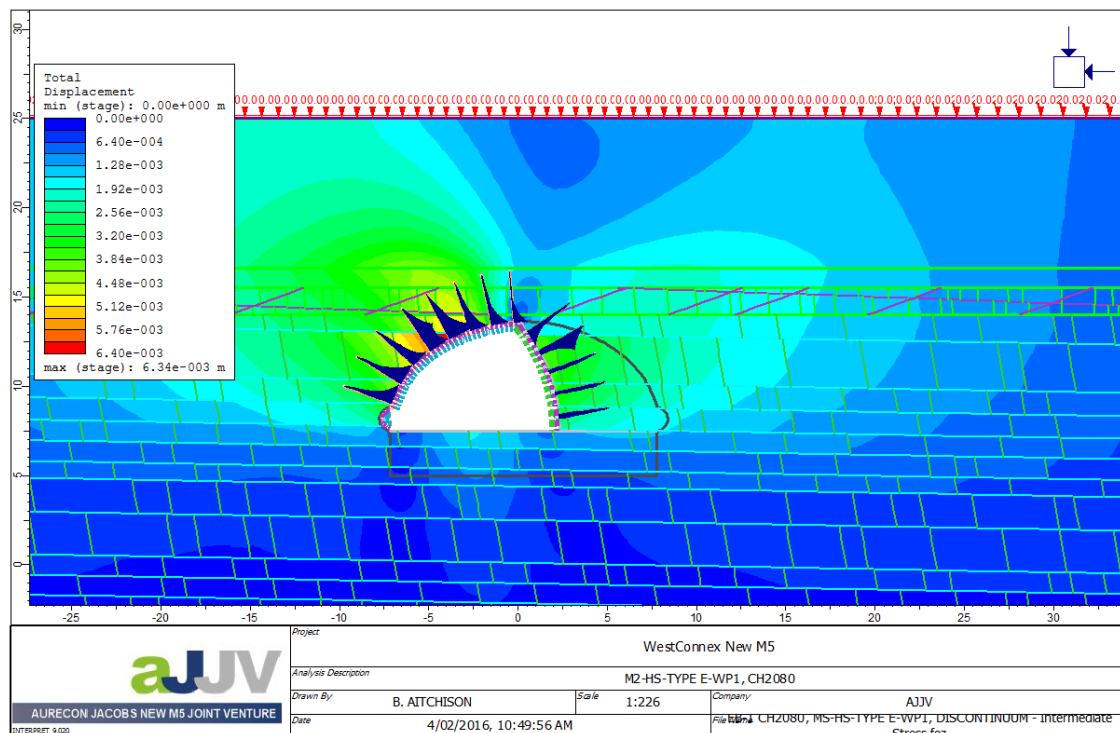


Figure 13 EB-1 CH2080 M2-HS-TYPE E-WP1-S – 50% RELAX – INTERMEDIATE STRESS – AT COMPLETION OF HEADING 1

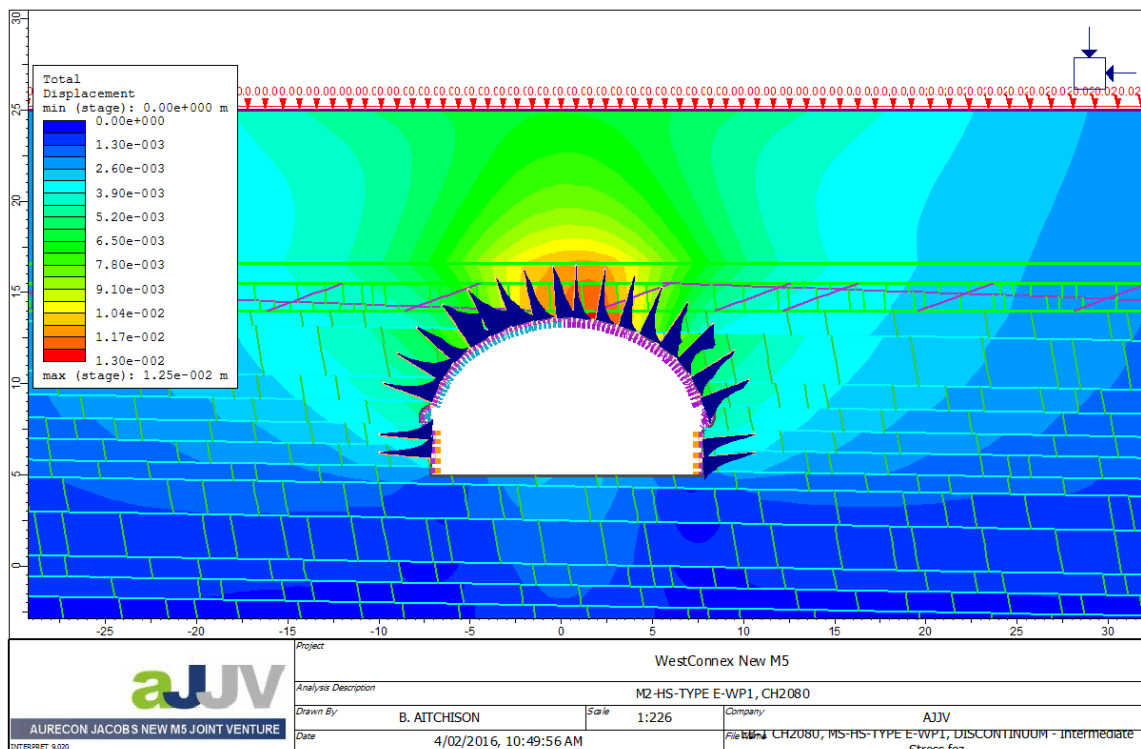


Figure 14 EB-1 CH2080 M2-HS-TYPE E-WP1-S – 50% RELAX – INTERMEDIATE STRESS – AT COMPLETION OF BOTH HEADINGS

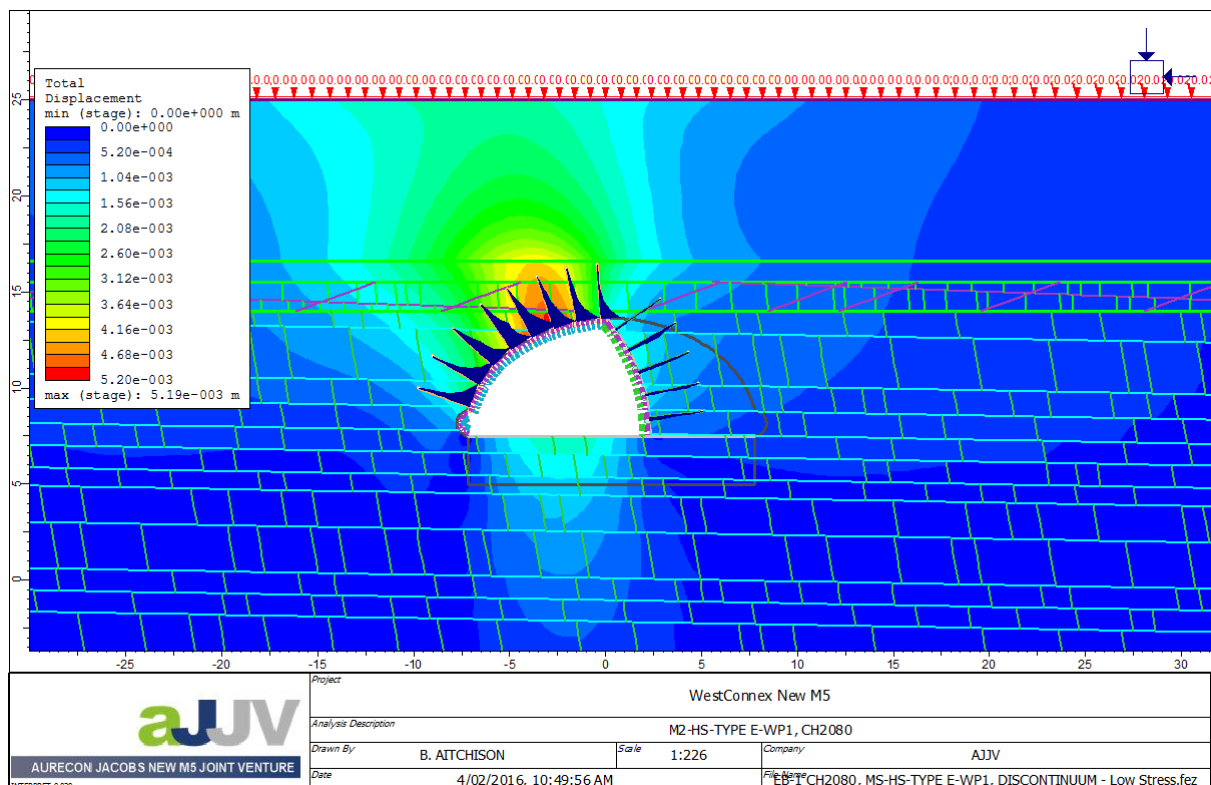


Figure 15 EB-1 CH2080 M2-HS-TYPE E-WP1-S – 50% RELAX – LOW STRESS - AT COMPLETION OF HEADING 1

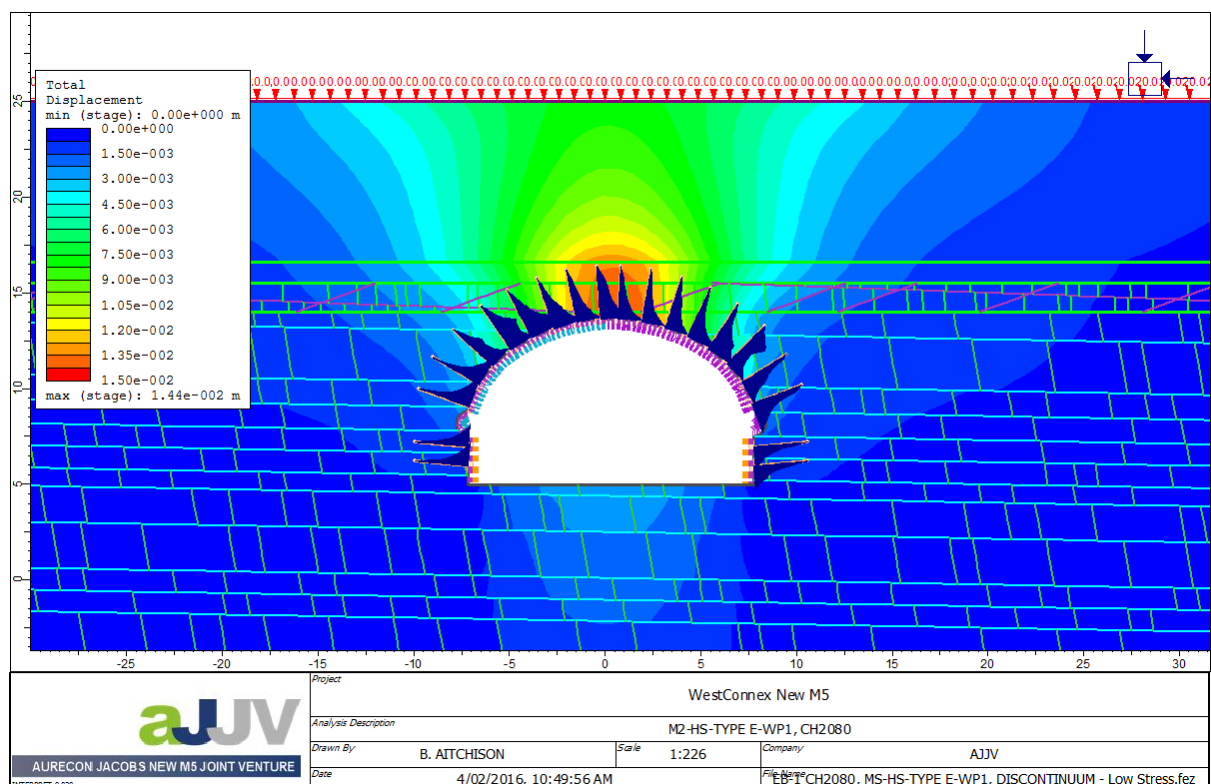


Figure 16 EB-1 CH2080 M2-HS-TYPE E-WP1-S – 50% RELAX – LOW STRESS – AT COMPLETION OF BOTH HEADINGS

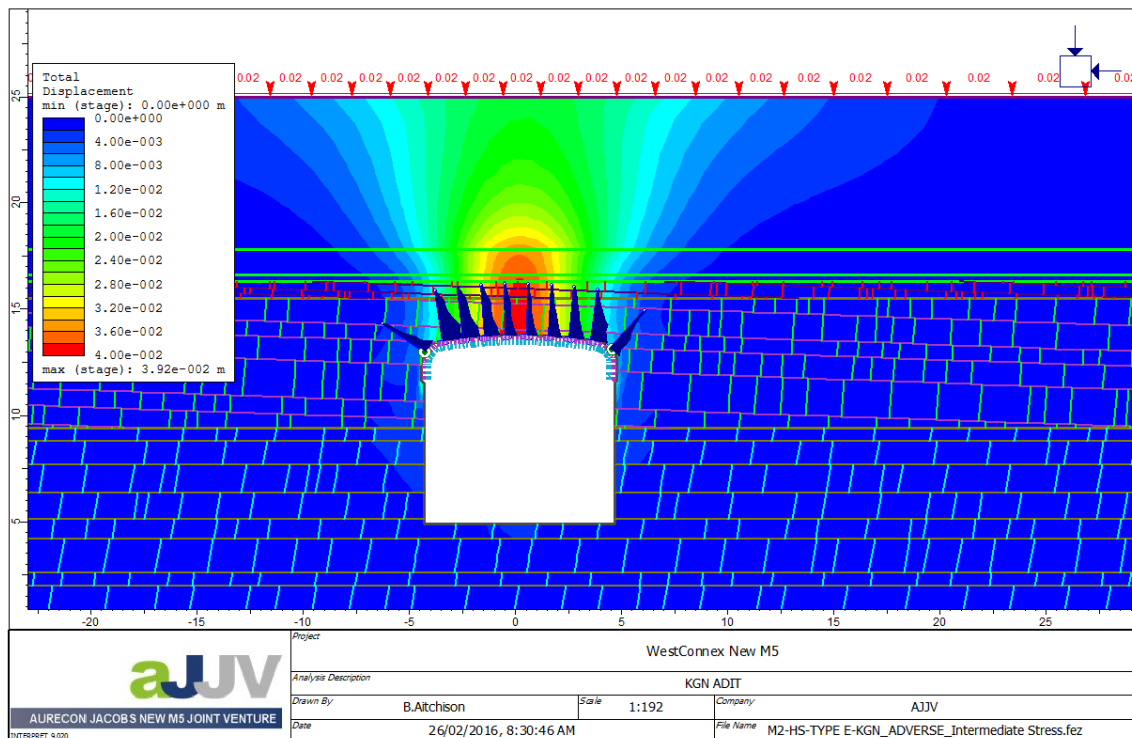


Figure 17 EB-2 CH2090 M2-HS-TYPE E-KGN – 50% RELAX – INTERMEDIATE STRESS

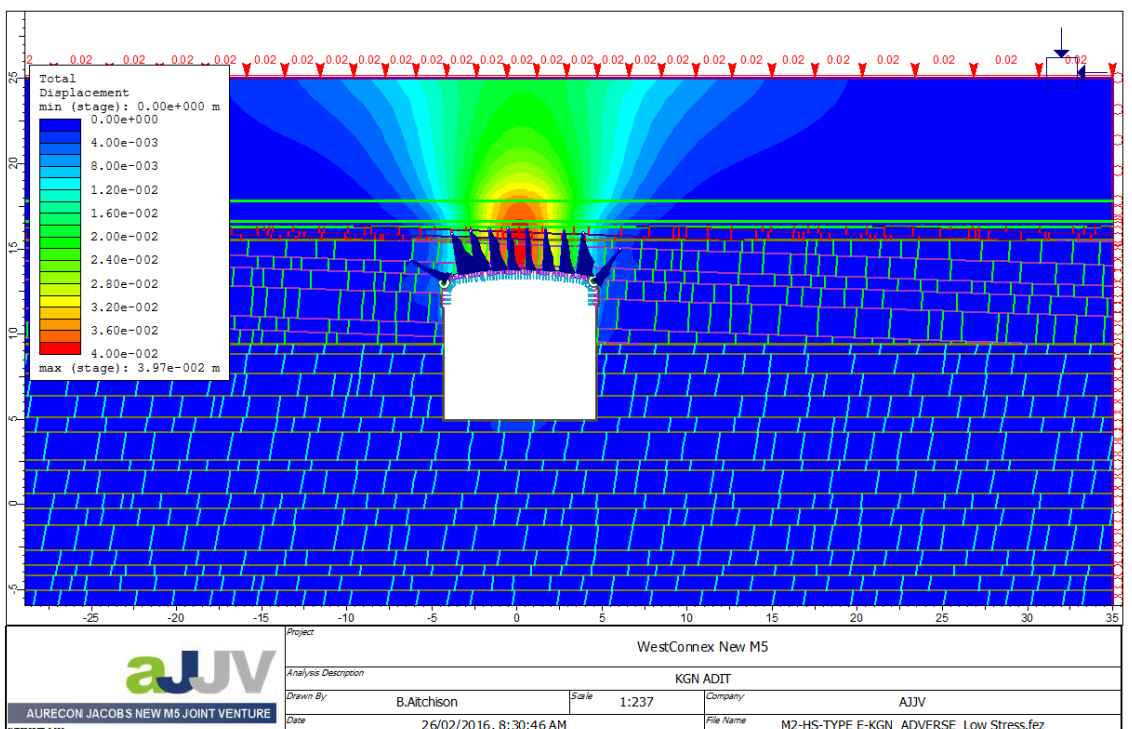


Figure 18 EB-2 CH2090 M2-HS-TYPE E-KGN – 50% RELAX –LOW STRESS

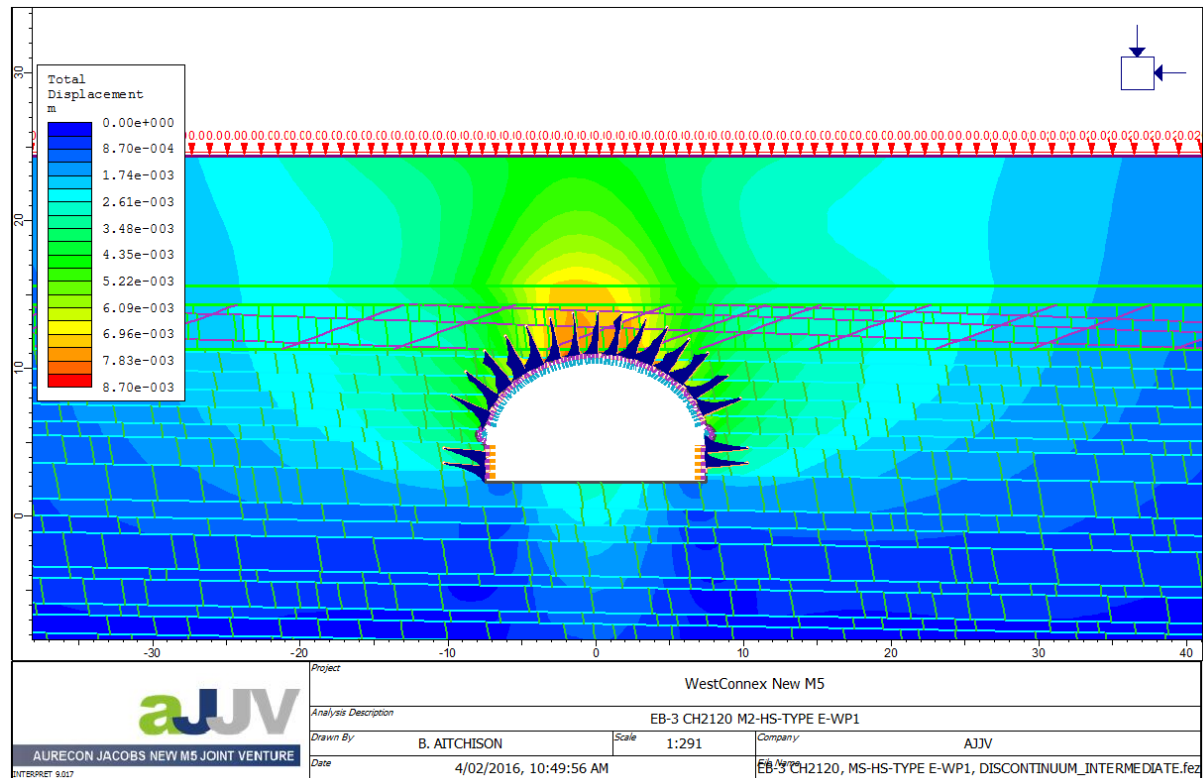


Figure 19 EB-3 CH2120 M2-HS-TYPE E-WP1 – 50% RELAX – INTERMEDIATE STRESS

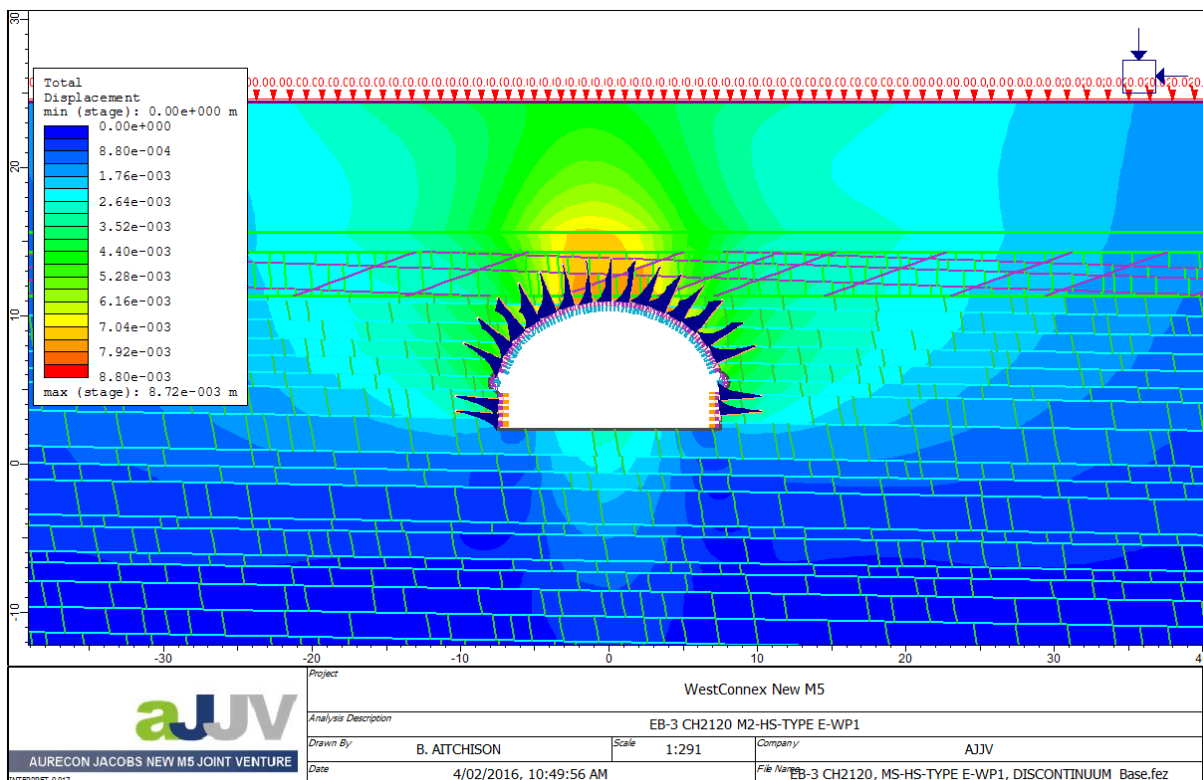


Figure 20 EB-3 CH2120 M2-HS-TYPE E-WP1 – 50% RELAX – TYPICAL STRESS

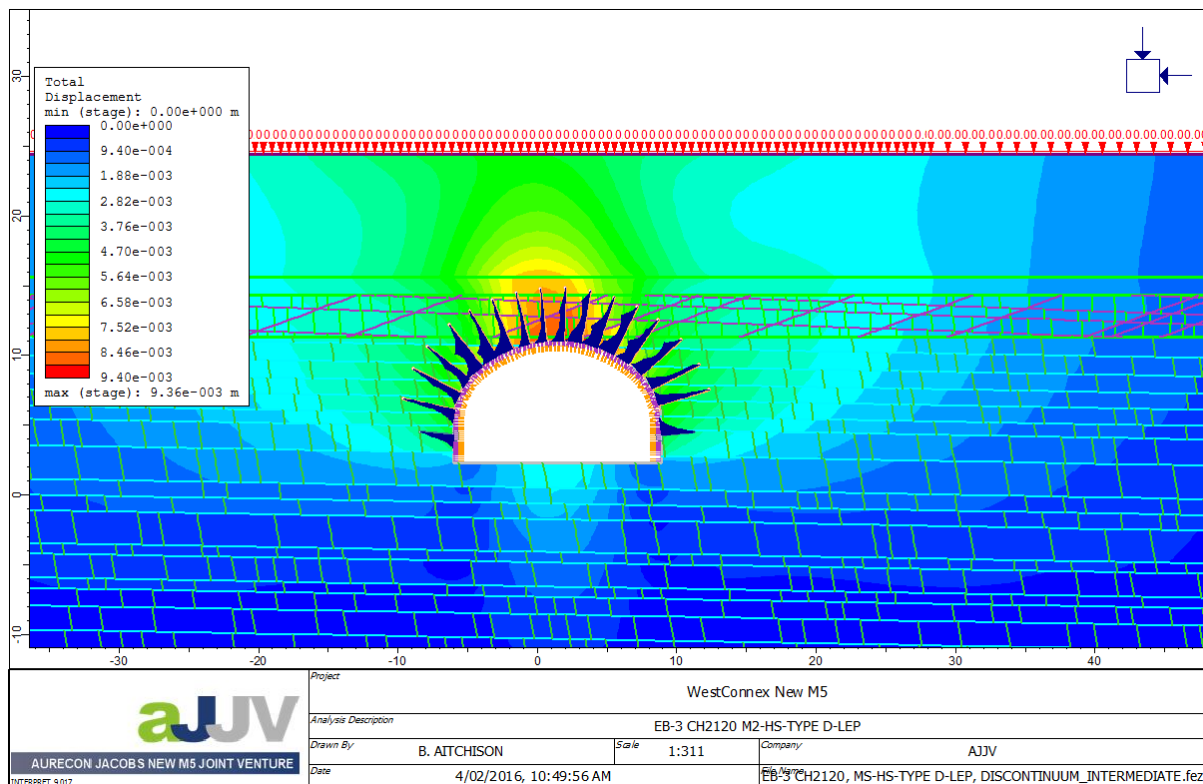


Figure 21 EB-3 CH2120 M2-HS-TYPE D-LEP – 50% RELAX – INTERMEDIATE STRESS

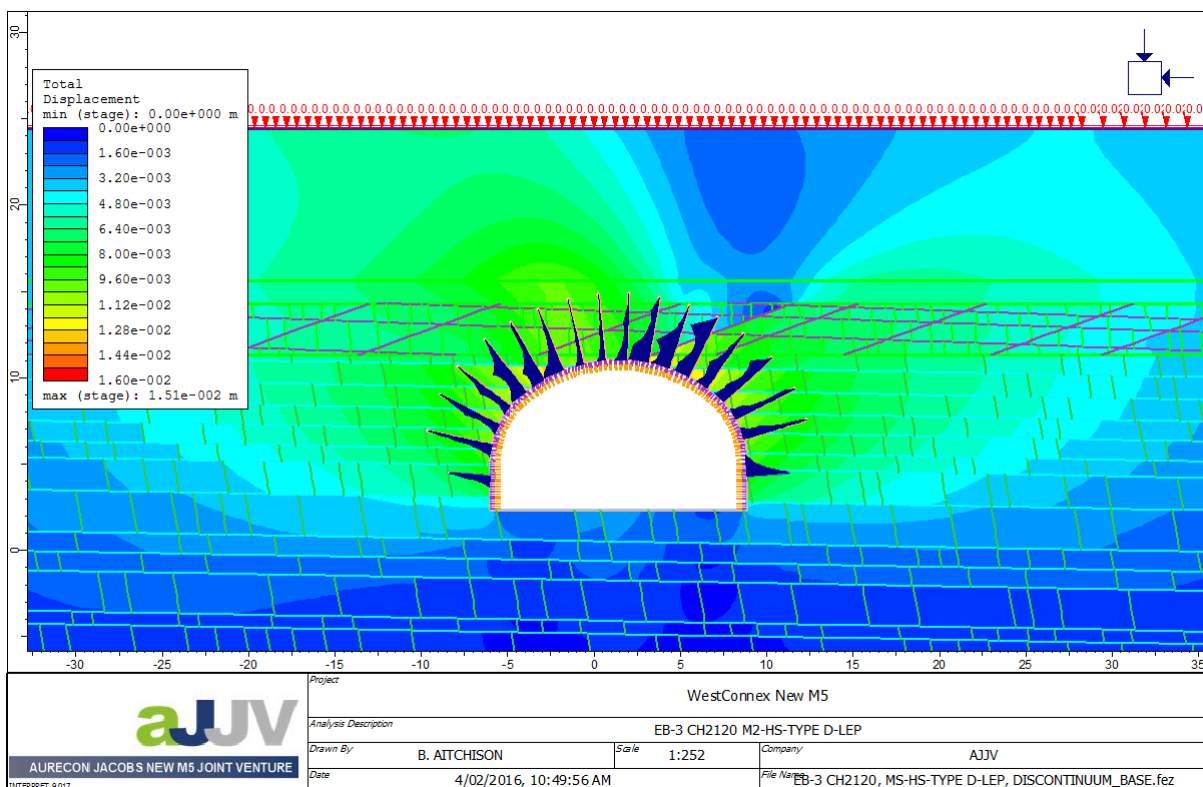


Figure 22 EB-3 CH2120 M2-HS-TYPE D-LEP – 50% RELAX – TYPICAL STRESS

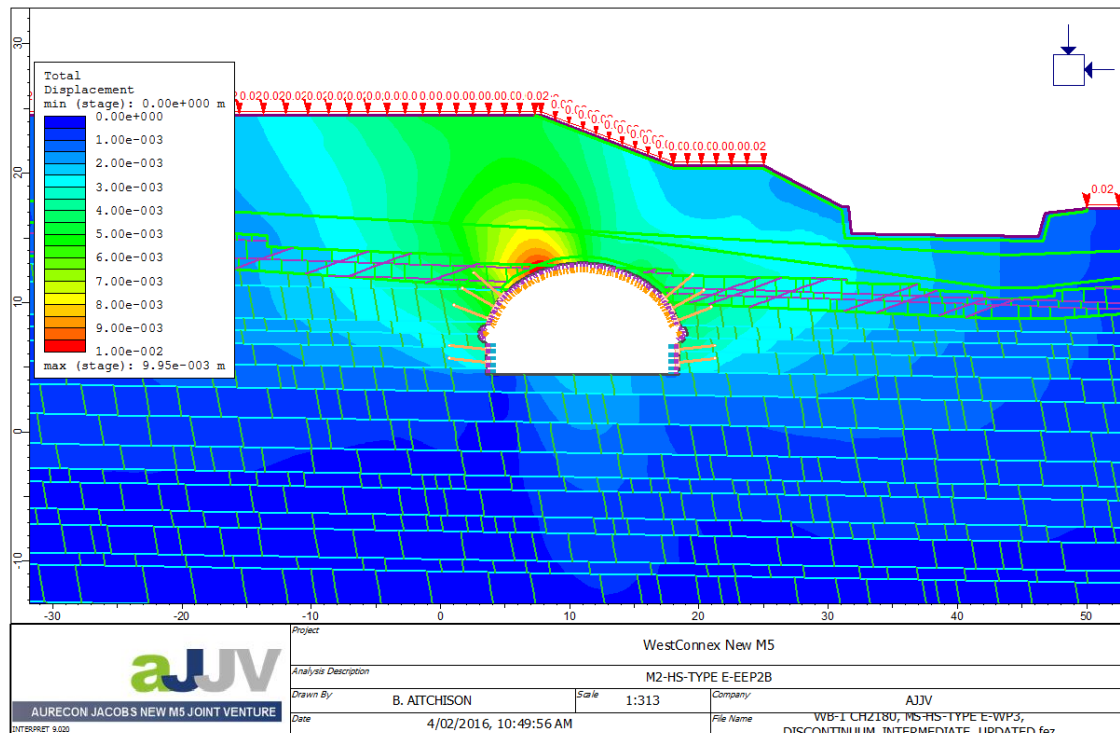


Figure 23 WB-1 CH2180 M2-HS-TYPE E-WP3 – 50% RELAX – INTERMEDIATE STRESS

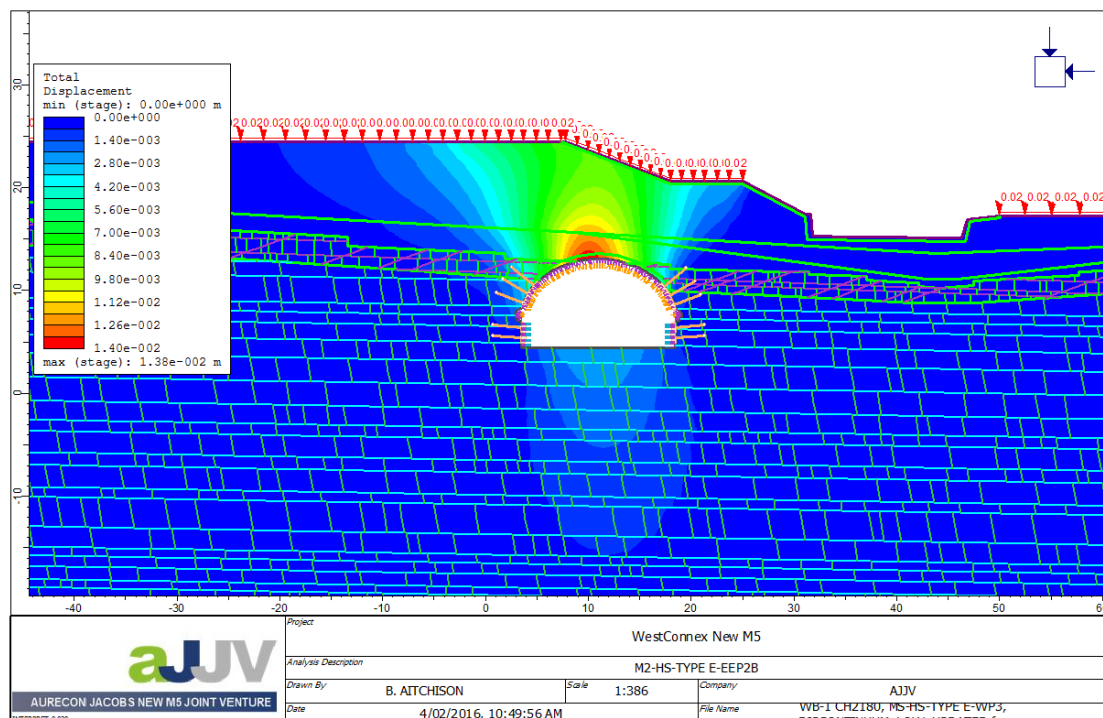


Figure 24 WB-1 CH2180 M2-HS-TYPE E-WP3 – 50% RELAX – LOW STRESS

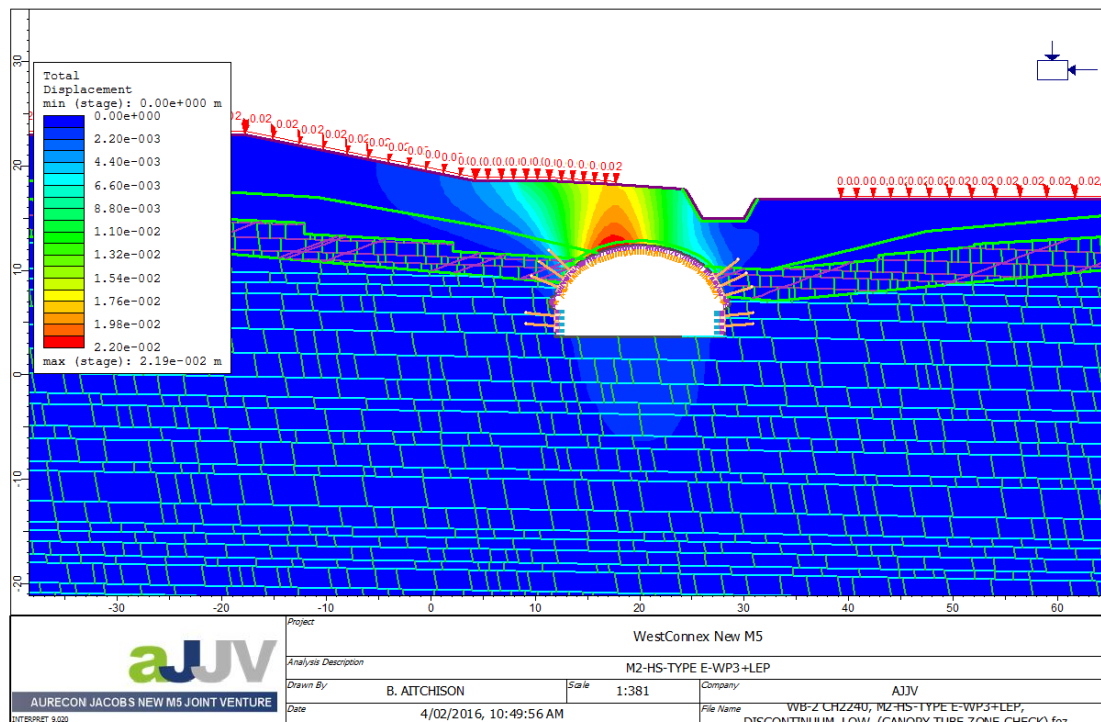


Figure 25 WB-2 CH2240 M2-HS-TYPE E-WP3-LEP – 50% RELAX – LOW STRESS

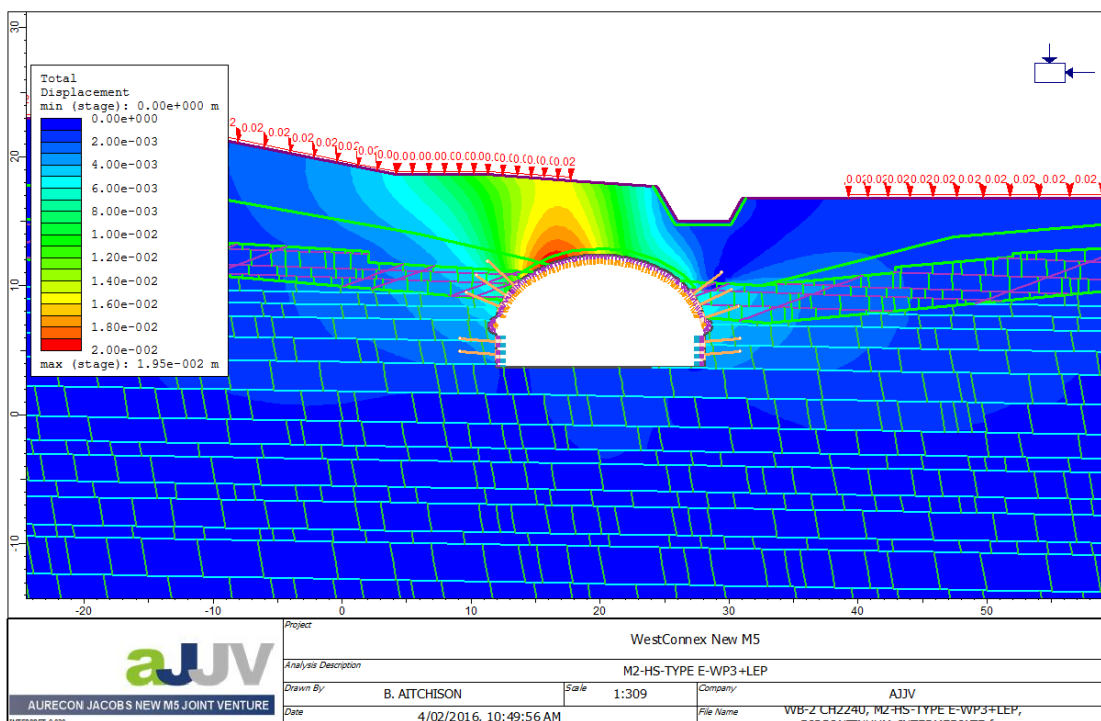


Figure 26 WB-2 CH2240 M2-HS-TYPE E-WP3-LEP – 50% RELAX – INTERMEDIATE STRESS



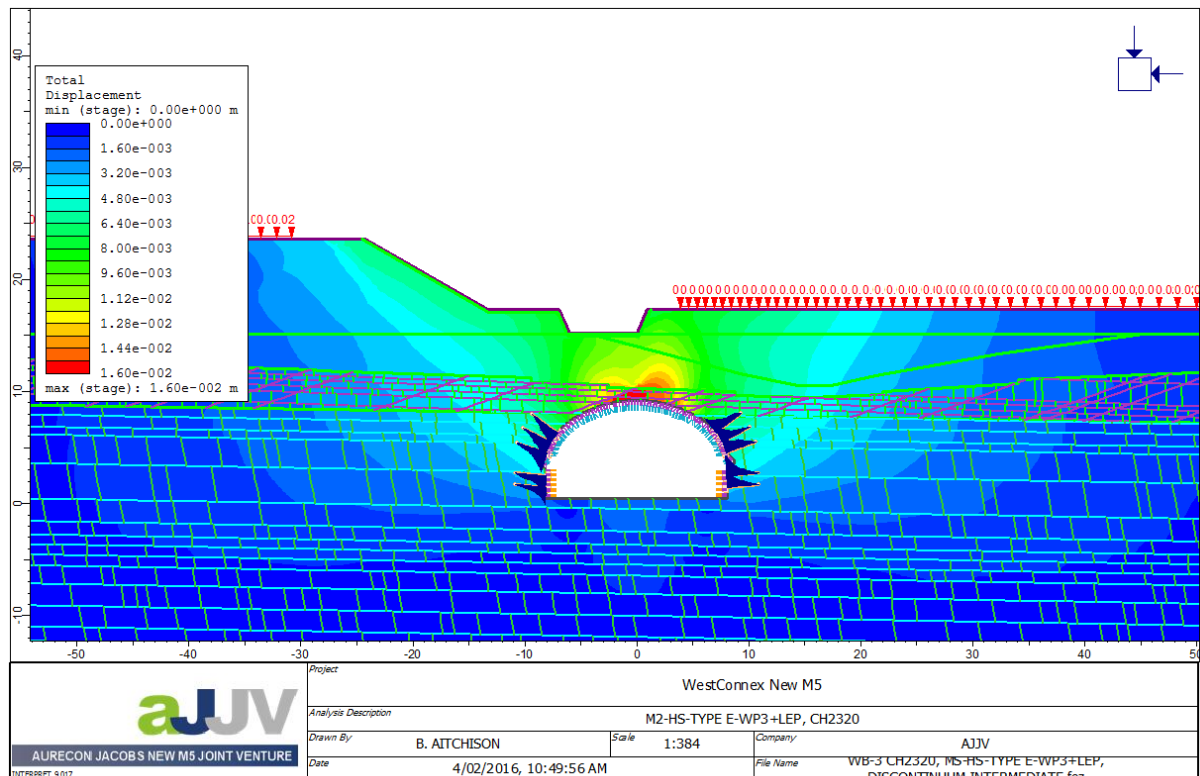


Figure 27 WB-3 CH2320 M2-HS-TYPE E-WP3-LEP – 50% RELAX – INTERMEDIATE STRESS

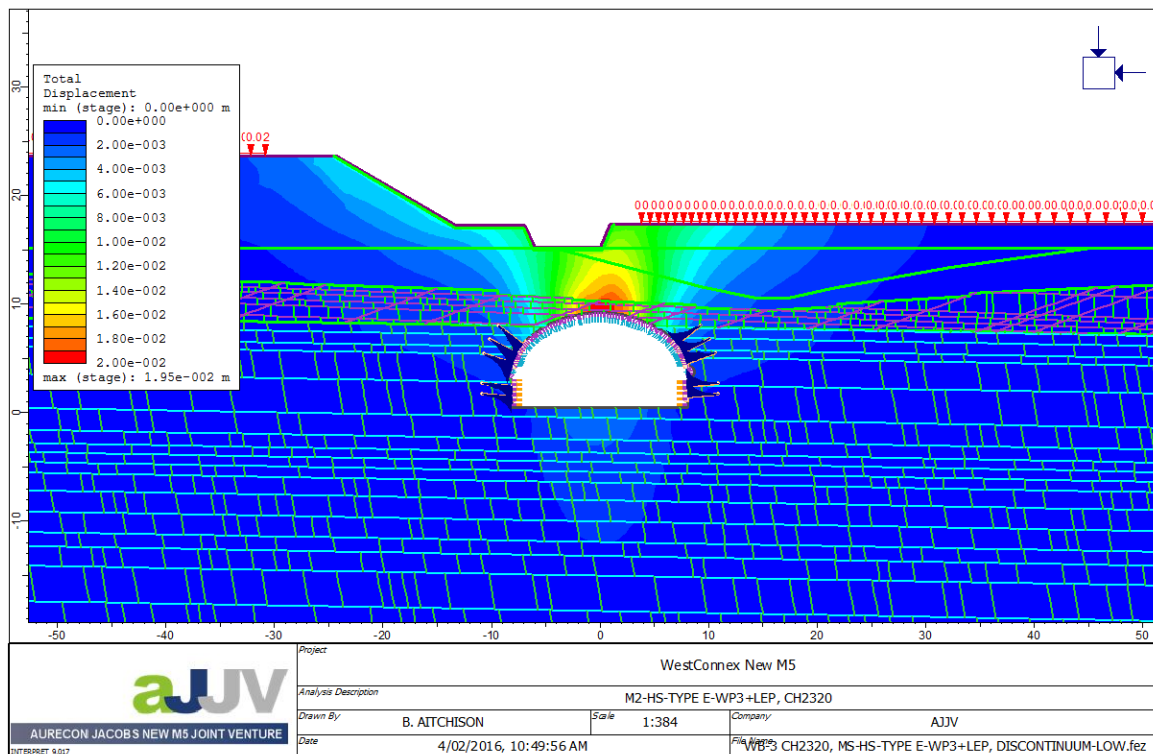


Figure 28 WB-3 CH2320 M2-HS-TYPE E-WP3-LEP – 50% RELAX – LOW STRESS

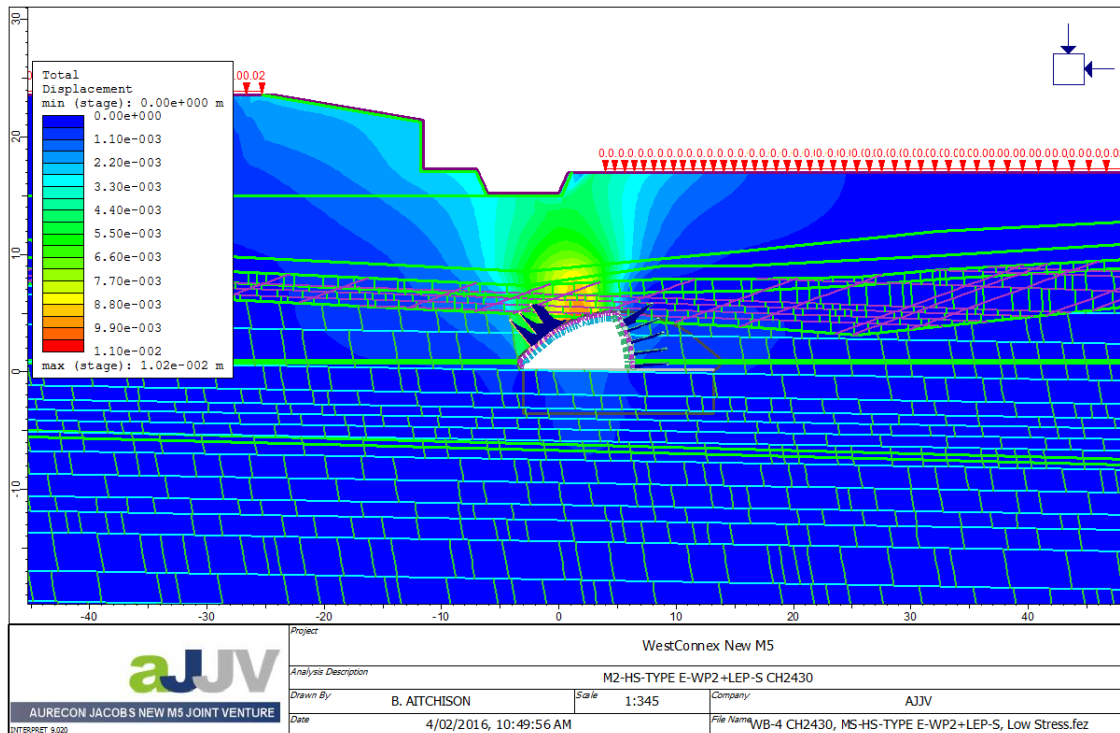


Figure 29 WB-4 CH2420 M2-HS-TYPE E-WP2-LEP-S-50% RELAX – LOW STRESS - AT COMPLETION OF HEADING 1

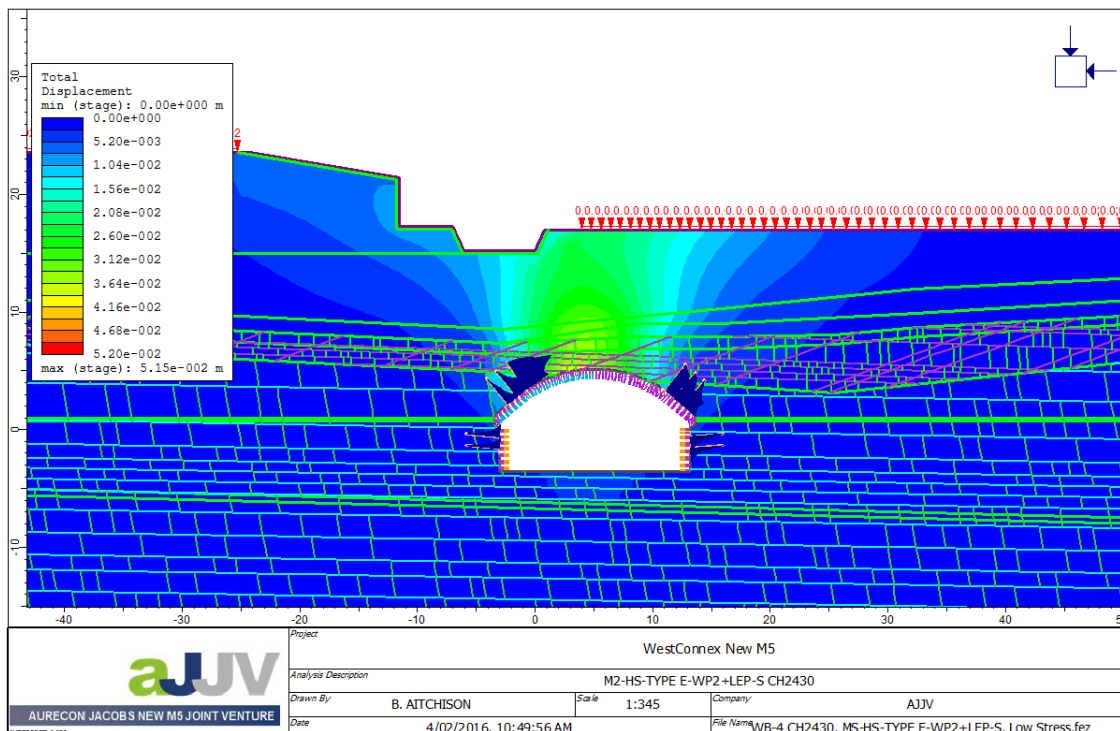


Figure 30 WB-4 CH2420 M2-HS-TYPE E-WP2-LEP-S-50% RELAX – LOW STRESS - AT COMPLETION OF BOTH HEADINGS

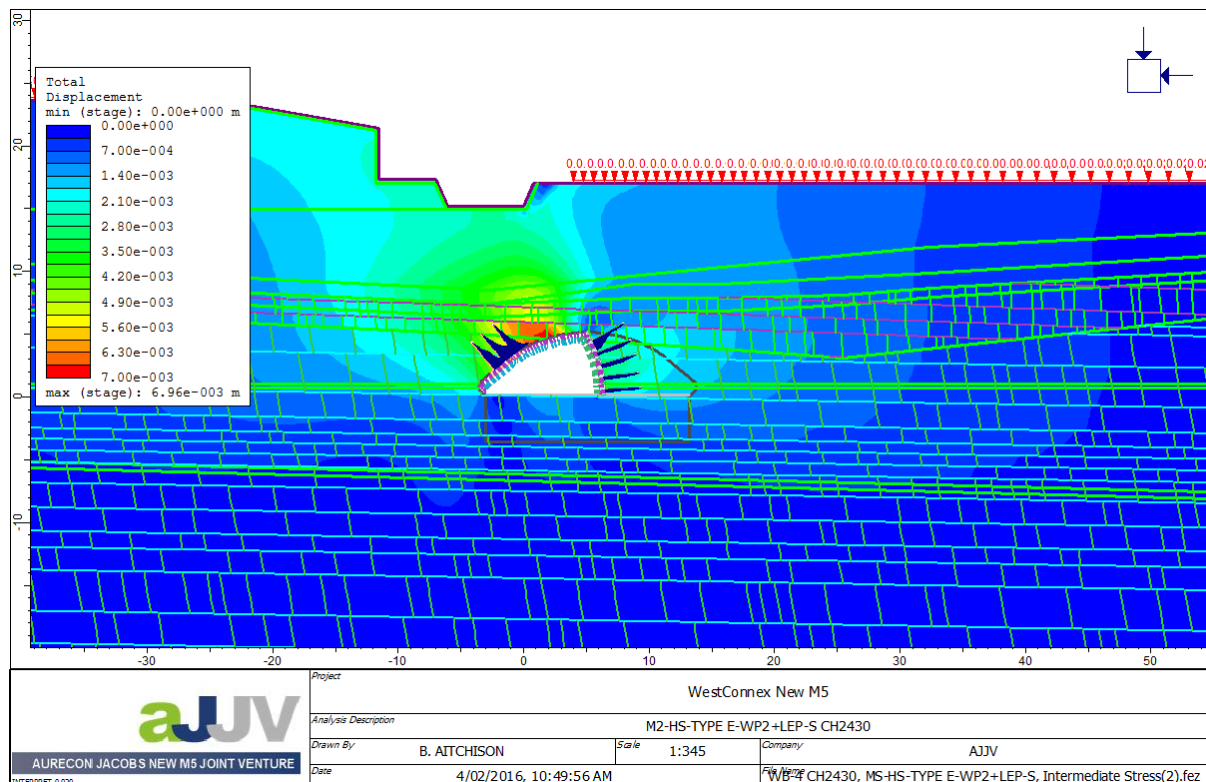


Figure 31 WB-4 CH2420 M2-HS-TYPE E-WP2-LEP-S-50% RELAX – INTERMEDIATE STRESS - AT COMPLETION OF HEADING 1

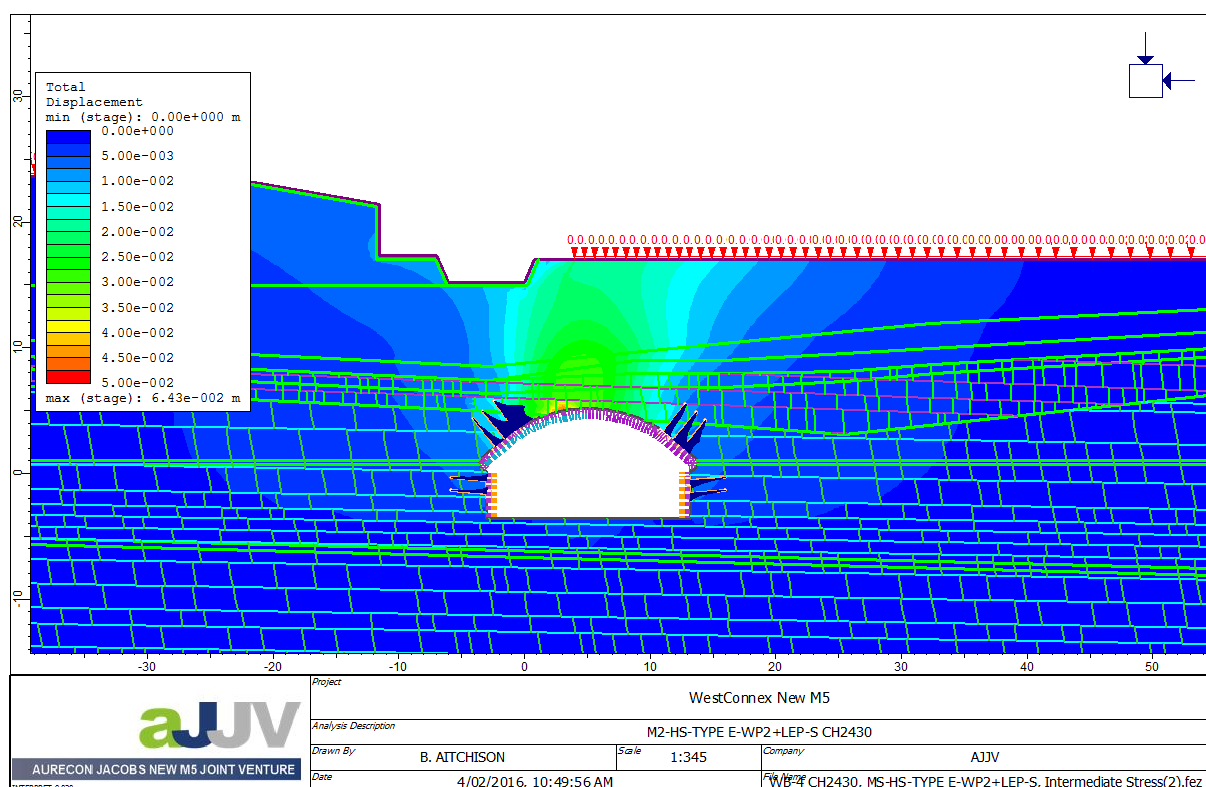


Figure 32 WB-4 CH2420 M2-HS-TYPE E-WP2-LEP-S-50% RELAX – INTERMEDIATE STRESS - AT COMPLETION OF BOTH HEADINGS

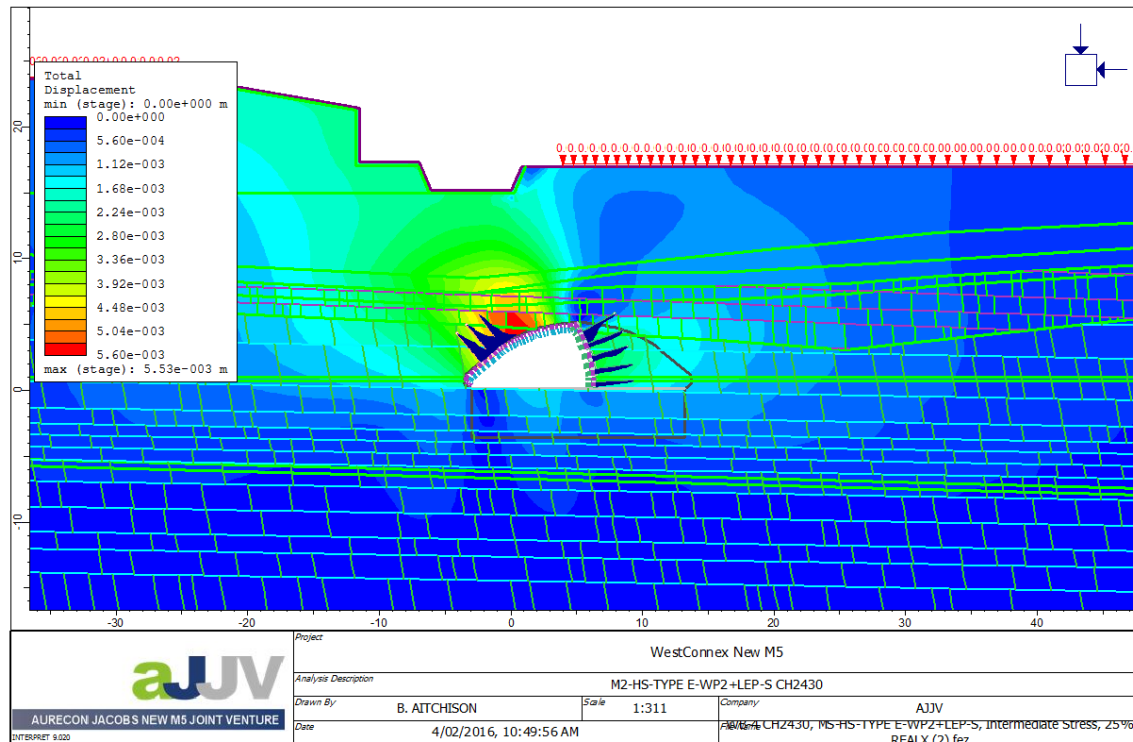


Figure 33 WB-4 CH2420 M2-HS-TYPE E-WP2-LEP-S-25% RELAX – INTERMEDIATE STRESS - AT COMPLETION OF HEADING 1

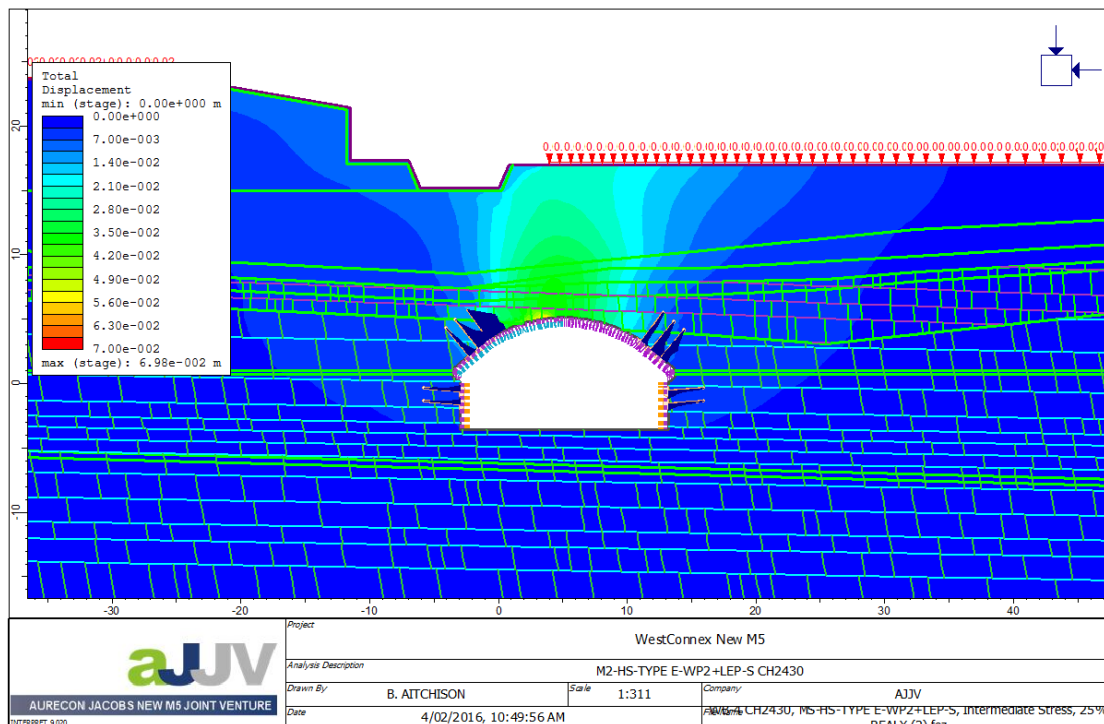


Figure 34 WB-4 CH2420 M2-HS-TYPE E-WP2-LEP-S-25% RELAX – INTERMEDIATE STRESS - AT COMPLETION OF BOTH HEADINGS

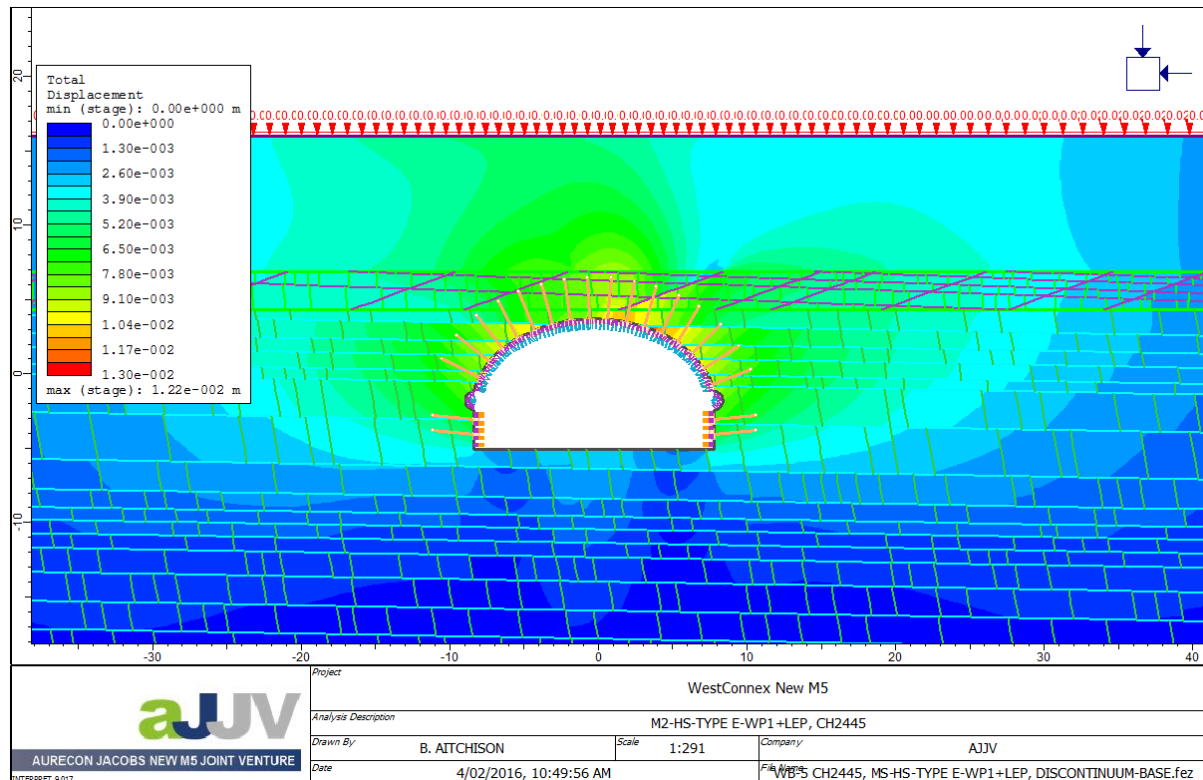


Figure 35 WB-5 CH2445 M2-HS-TYPE E-WP3-LEP – 50% RELAX – TYPICAL STRESS

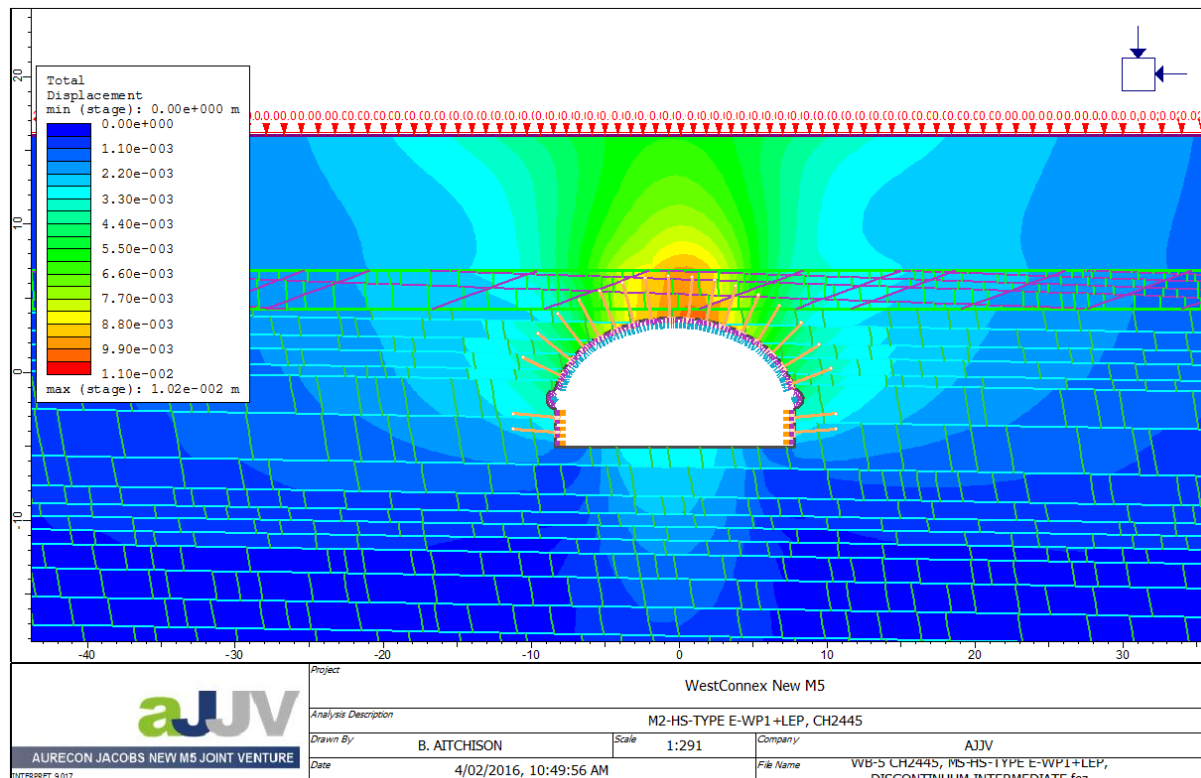


Figure 36 WB-5 CH2445 M2-HS-TYPE E-WP3-LEP – 50% RELAX – INTERMEDIATE STRESS

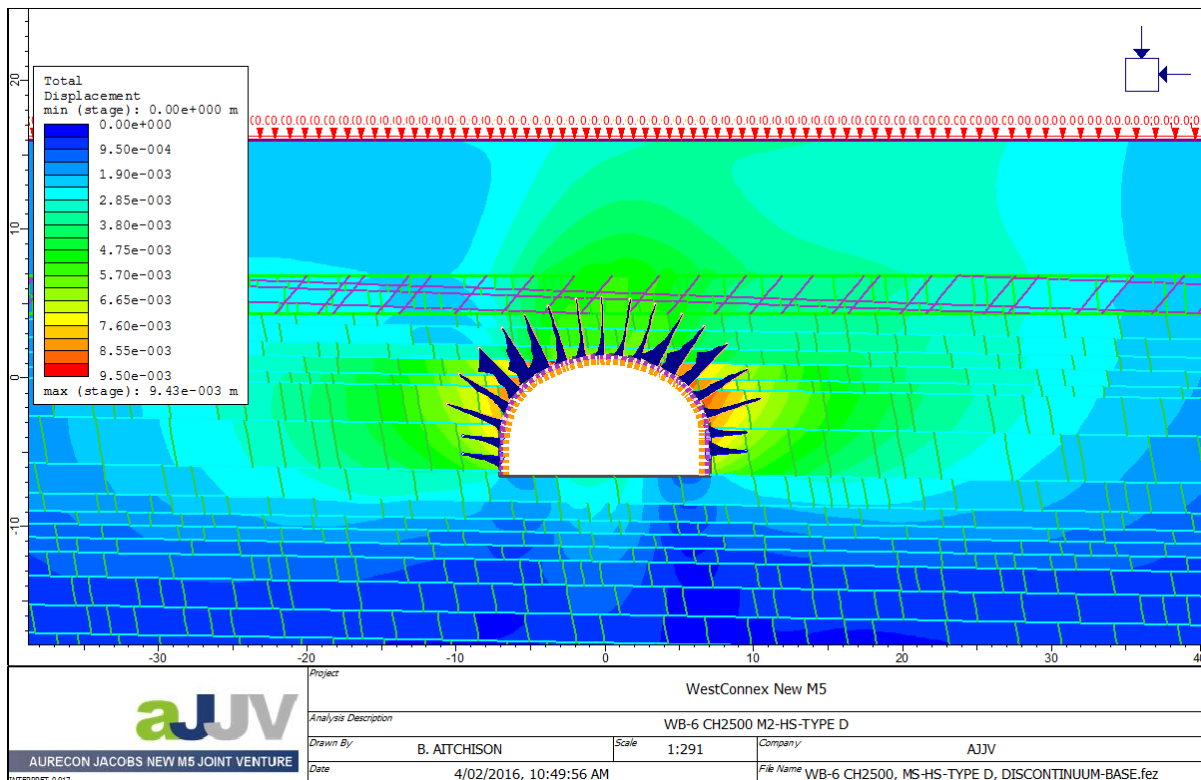


Figure 37 WB-6 CH2500 M2-HS-TYPE D – 50% RELAX – TYPICAL STRESS

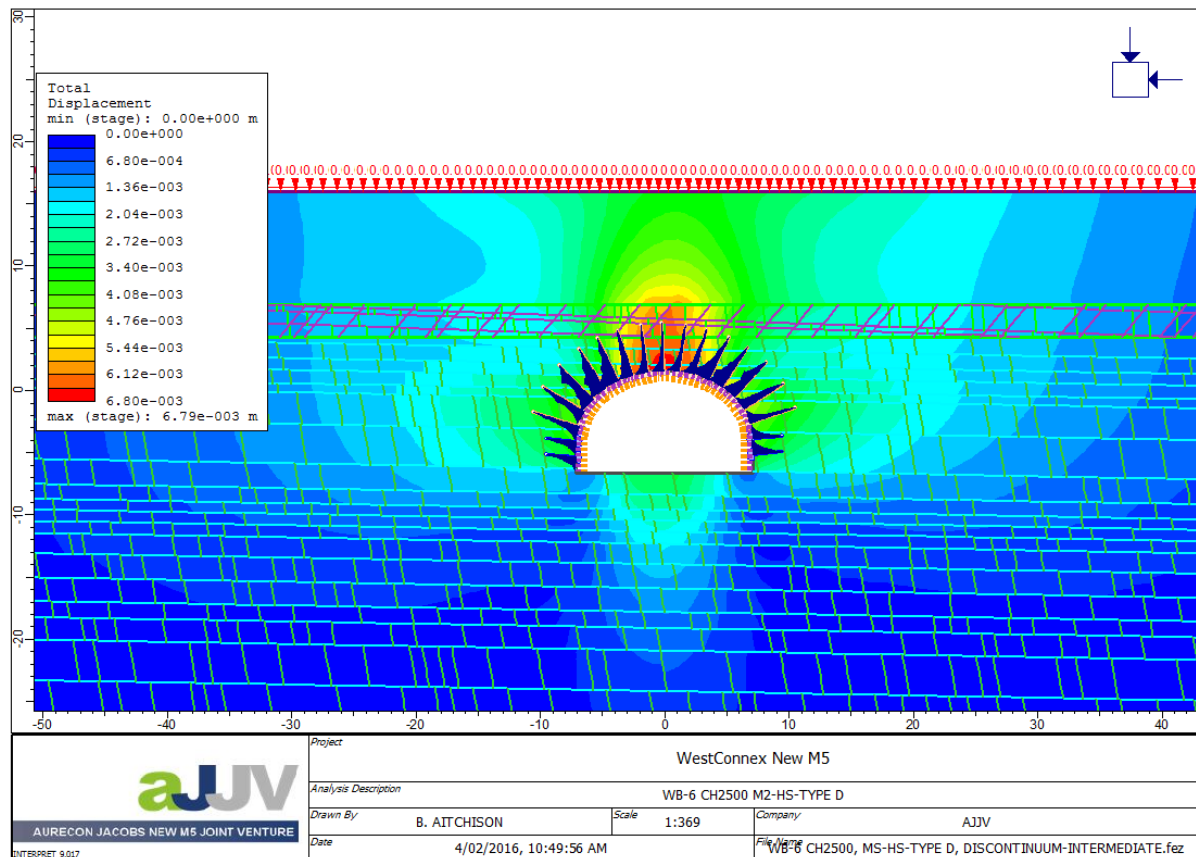


Figure 38 WB-6 CH2500 M2-HS-TYPE D – 50% RELAX – INTERMEDIATE STRESS

## 1.5.2 Shotcrete design results

The ultimate limit state shotcrete design is presented in Figure 39 and Figure 58. The lining actions (bending moment, axial force and shear force) are extracted from the analysis and compared to the M-N and V-N interaction diagrams. The results relate to the primary lining only.