5.4 Stress in Entry Roof in a Multiple-Panel System

After a panel is mined out, the tailgates in the adjacent panel will be subjected to the side abutment pressure caused by the mined-out panel. Because of the gob effects, the stress in the tailgate roof may be different from that in a single panel. In addition, the maximum horizontal stress can be either from the mined-out panel side (called the gob side) or from the solid coal side (namely, from the headgate side). Since the maximum horizontal stress is from different direction, the stress in the headgate roof may be different. In this section, the Von-Mises stress, the maximum and the minimum principal stresses at the roof line level near the T-junctions of the mining panel are analyzed.

Based on the previous study, the stress in the roof of the headgate 1 and the tailgate 1 is the largest, because they are subjected to the large front abutment pressure caused by the lomgwall mining. Therefore, in the following, the stresses in headgate 1 and tailgate 1 are studied.

5.4.1 Von-Mises Stress in Headgate and Tailgate

Von-Mises Stress in Headgate

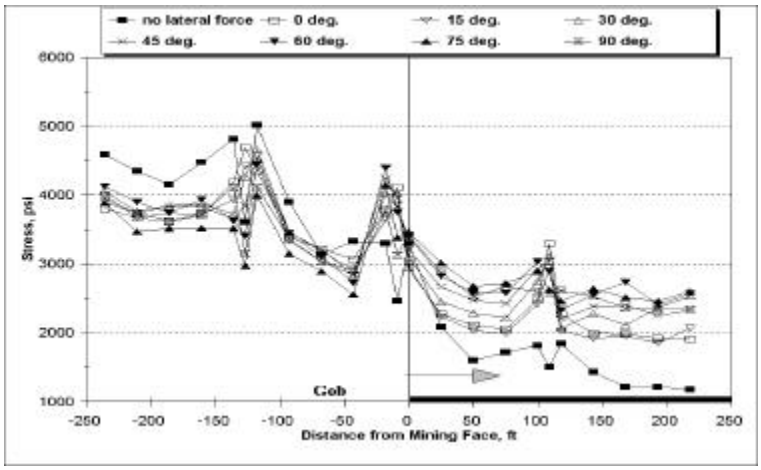
Generally, the headgate is subjected to smaller loading than the tailgate, because the tailgate is subjected to the side abutment pressure, to some degree, caused by the adjacent mined-out panel. Generally, the Von-Mises stress is concentrated at the rib side. At the entry center, the stress is smaller. Therefore, the Von-Mises stresses at the roof line level are analyzed only along the two entry rib sides.

Fig. 5-30 shows the Von-Mises stress along the rib sides and at the T-junction, when the maximum horizontal stress is from the mined-out panel (the gob side). Along line L, the stress outby the longwall face increases slightly with the stress angle. But, the Von-Mises stress at the T-junction subject to the horizontal stress is slightly larger than that without the horizontal stress, as shown in Fig. 5-30(a). Along line R, the Von-Mises stress subject to the horizontal stress is larger than that without the horizontal stress. The stress at the roof line level increases with the stress angle, as shown in Fig. 5-30(b). At the T-junction, the stress reaches the maximum. At point P1, the Von-Mises stress increases with the stress angle from 0^0 to 60^0, and then stays nearly unchanged from 60^0

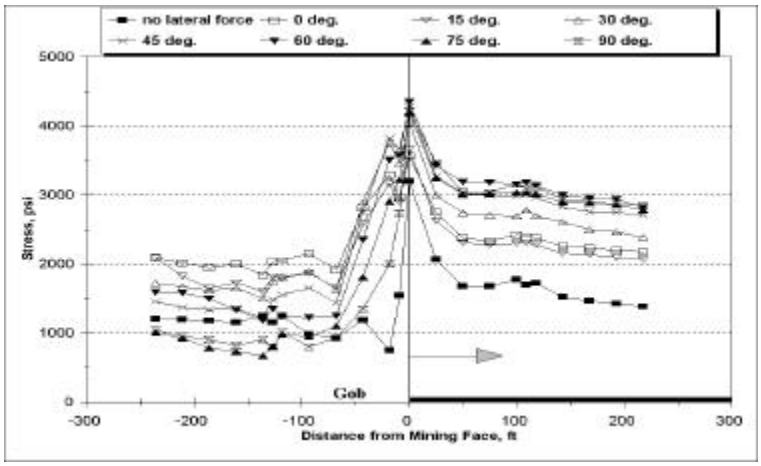
to 90^0. At point P3, the stress increases with the stress angle from 0^0 to 60^0, and then decreases slightly from 60^0 to 90^0, as shown in Fig. 5-30(c). The stress at Point P3 is larger than that at point P1. The locations of points P1 and P3 are also shown in Fig. 5-30(c).

When the maximum horizontal stress is from the solid coal side (the headgate side), the Von-Mises stress at the roof line level is similar to that from the gob side, as shown in Fig. 5-31. At point P1, the Von-Mises stress increases with the stress angle from 0^0 to 90^0. But when the angle is less than 45^0, the stress change is very small. At point P3, the Von-Mises stress increases with the stress angle from 0^0 to 60^0, and then decreases slightly from 60^0 to 90^0. In this case, the Von-Mises stress at point P3 is also larger than that at point P1.

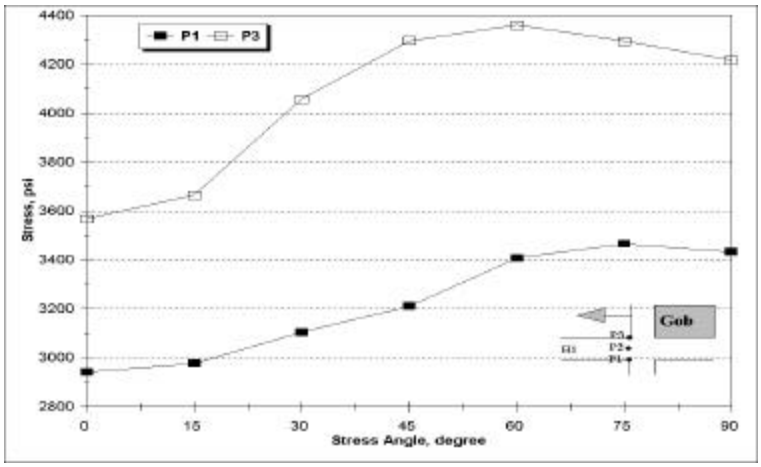
Fig. 5-32 shows the Von-Mises stresses at points P1 and P3 when the maximum horizontal stress is from the gob side and from the solid coal side, respectively. It indicates that the stress is larger when the maximum horizontal stress is from the gob side. Generally, the T-junction of the headgate is in the worst condition when the stress angle is equal to or larger than 60^0.



(a) along Line L

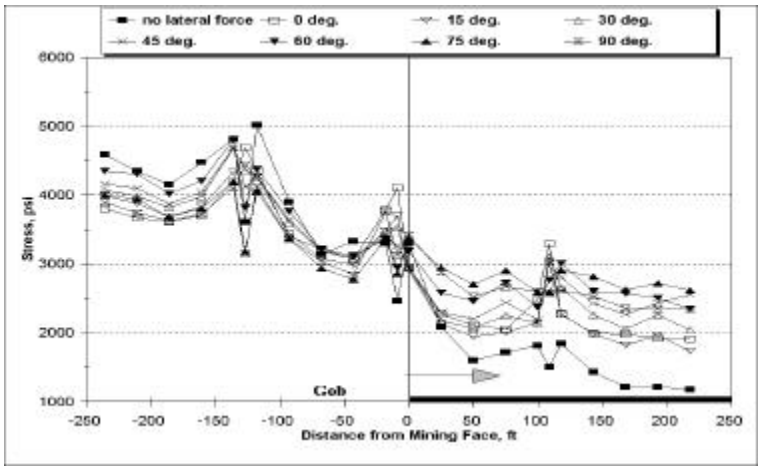


(b) along Line R

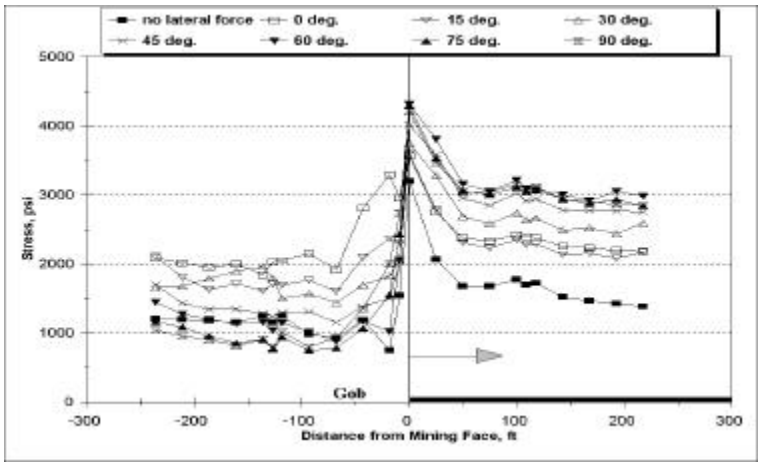


(c) at Poins P1 and P3

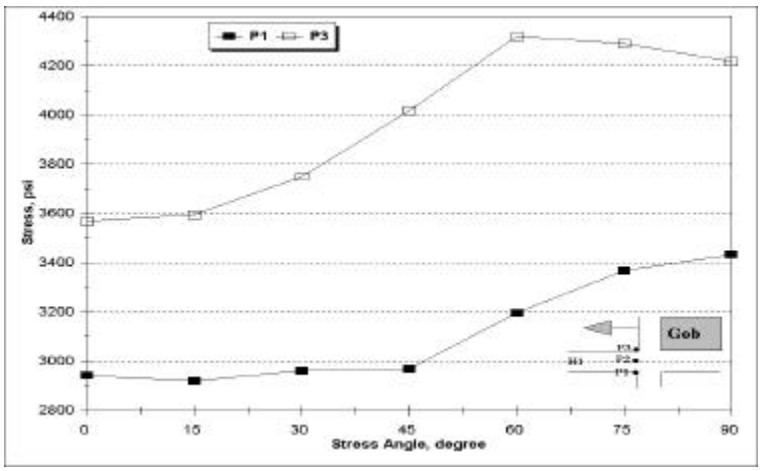
Fig. 5-30 Von-Mises Stress in Headgate 1 (σ_{hmax} from Gob Side)



(a) along Line L

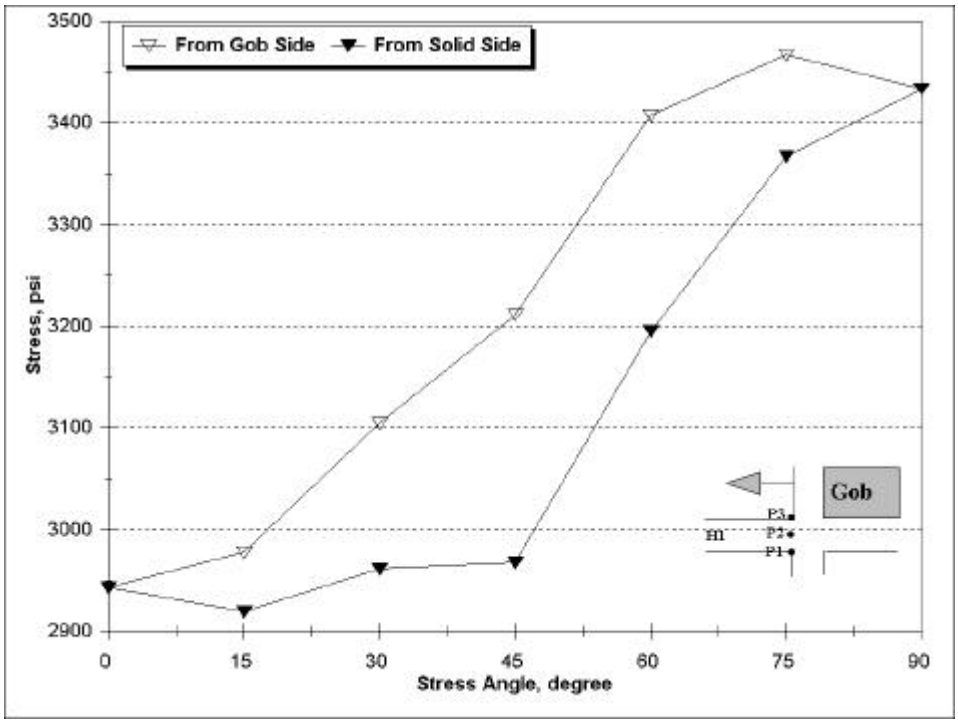


(b) along Line R

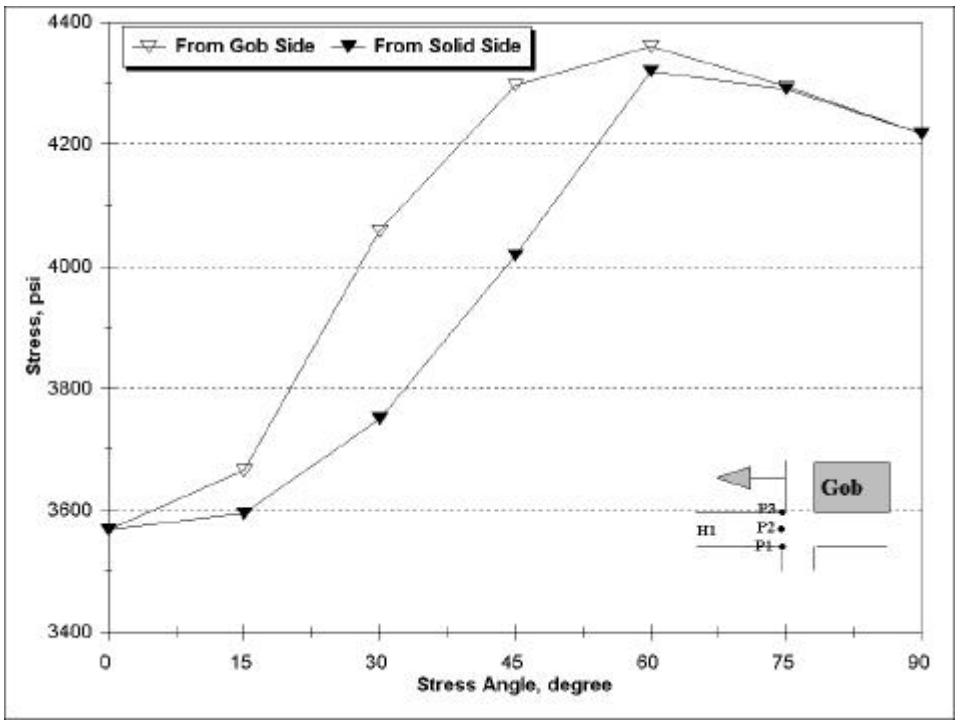


(c) at Points P1 and P3

Fig. 5-31 Von-Mises Stress in Headgate 1 (σ_{hmax} from Solid Coal Side)



(a) at Point P1



(b) at Point P3

Fig. 5-32 Comparison of Von-Mises Stress in Headgate 1

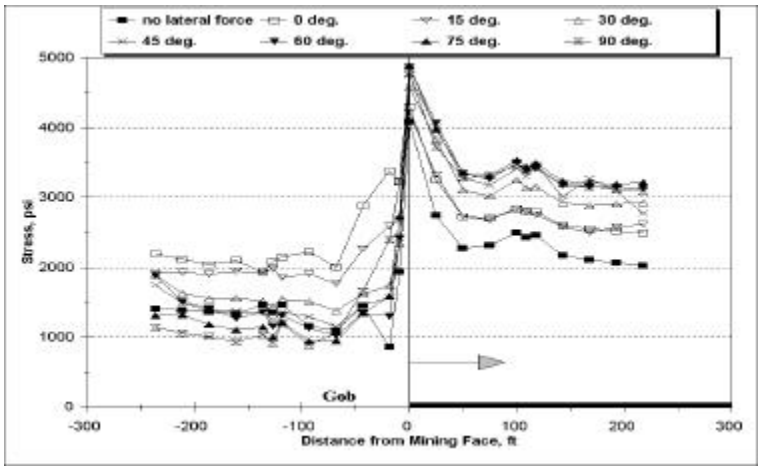
Von-Mises Stress in Tailgate

The Von-Mises stress at the roof line level in the tailgate is shown in Fig. 5-33, when the maximum horizontal stress is from the gob side. It is similar to that in the headgate. The Von-Mises stress is concentrated along the entry rib sides. It is larger than that without the horizontal stress. At the T-junction of the tailgate, the Von-Mises stress is the largest. At point P1, the stress increases with the stress angle from 0^0 to 90^0 while at point P3, it increases with the angle from 0^0 to 75^0, and then decreases slightly from 75^0 to 90^0, as shown in Fig. 5-33(c). Generally, the Von-Mises stress at point P3 is larger than that at point P1.

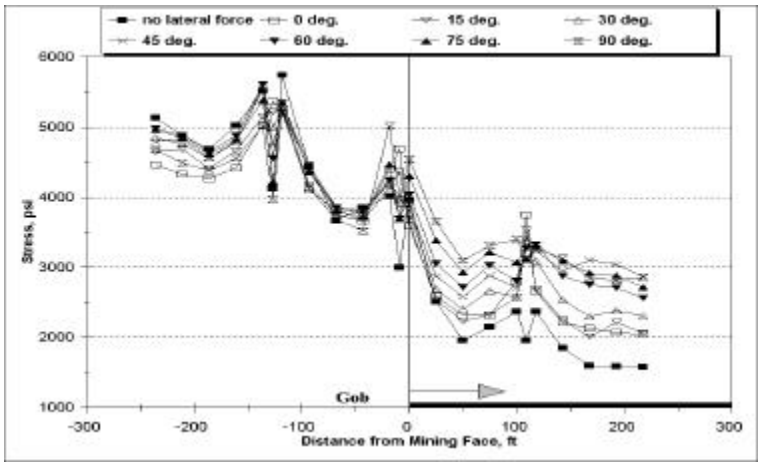
When the maximum horizontal stress is from the solid coal side, the Von-Mises stress in the tailgate is similar to that from the gob side, as shown in Fig. 5-34. At the T-junction, the Von-Mises stress is the largest. At point P1, the stress increases with the stress angle from 0^0 to 90^0. At point P3, the stress increases with the stress angle from 0^0 to 45^0, and then stays nearly unchanged from 45^0 to 90^0, as shown in Fig. 5-33(c).

In the tailgate, the Von-Mises stress at the T-junction is larger when the maximum horizontal stress is from the solid coal side, as shown in Fig. 5-35. It is different from that in the headgate. The reason is the gob effects. When the maximum horizontal stress is from the gob side, the T-junction in the tailgate will move toward the gob of the mining panel. This may cause the stress relief in the roof to some degree. When the horizontal stress is from the solid coal side, the roof will move toward the chain pillars. In this situation, the stress in the roof does not relieve.

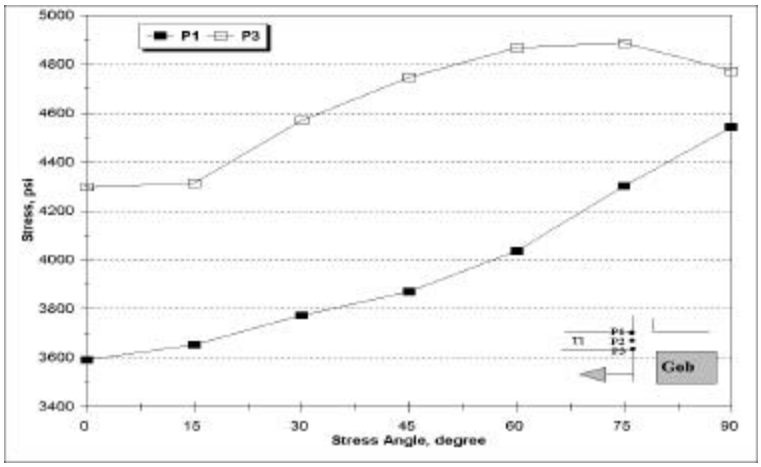
In the headgate, the situation just reverses. When the maximum horizontal stress is from the gob side, the roof at the T-junction will move toward the chain pillars. The stress in the roof is not relieved. When the horizontal stress is from the solid coal side, the roof may move toward the gob of the mining panel. In this case, if the frictional coefficient between the coal seam and the roof is small, the stress in the roof relieves significantly (see next chapter).



(a) along Line L

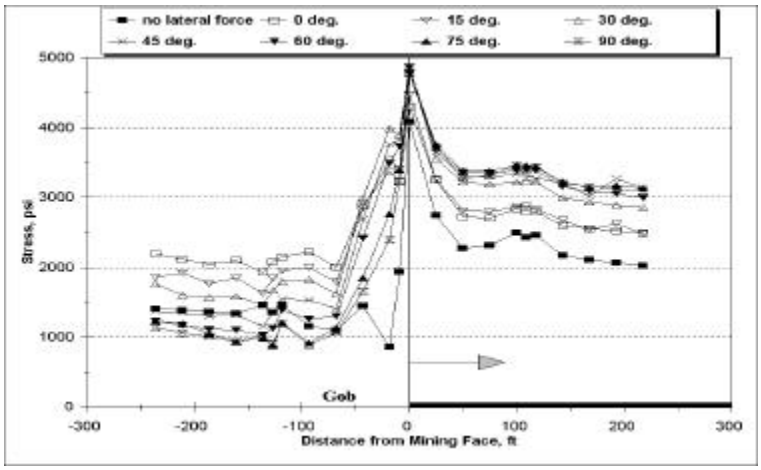


(b) along Line R

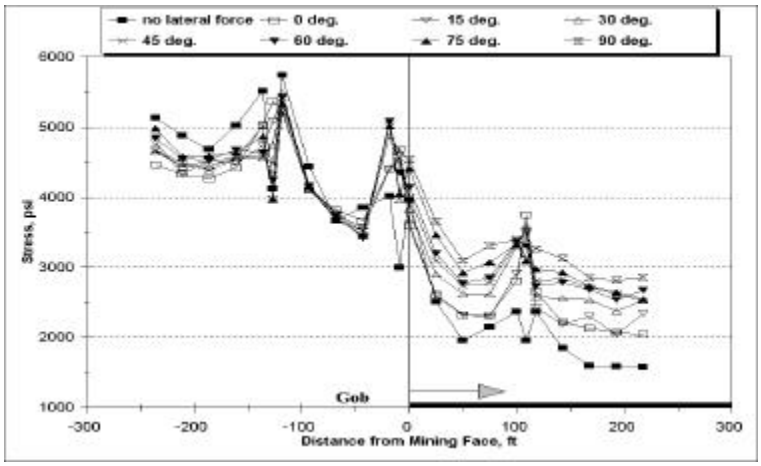


(c) at Points P1 and P3

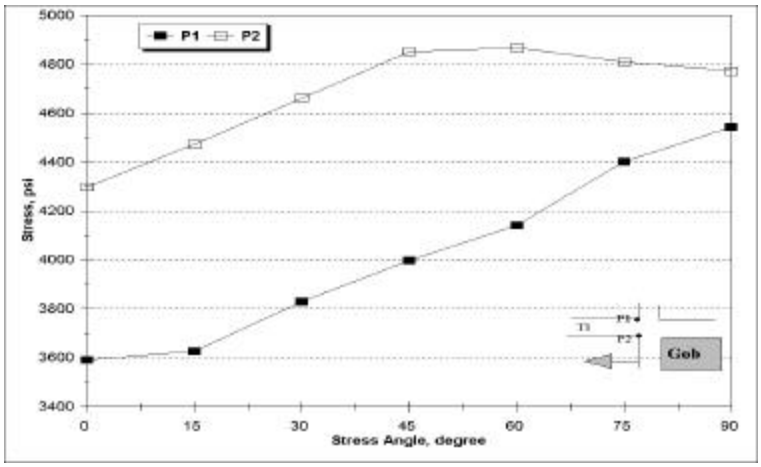
Fig. 5-33 Von-Mises Stress in Tailgate 1 (σ_{hmax} from Gob Side)



(a) along Line L

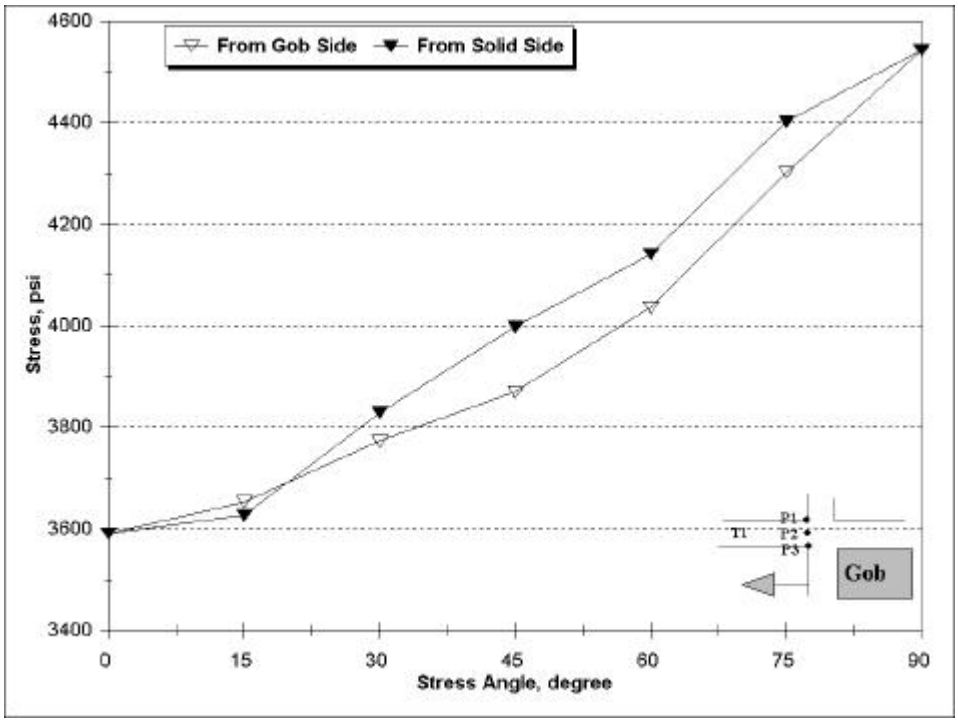


(b) along Line R

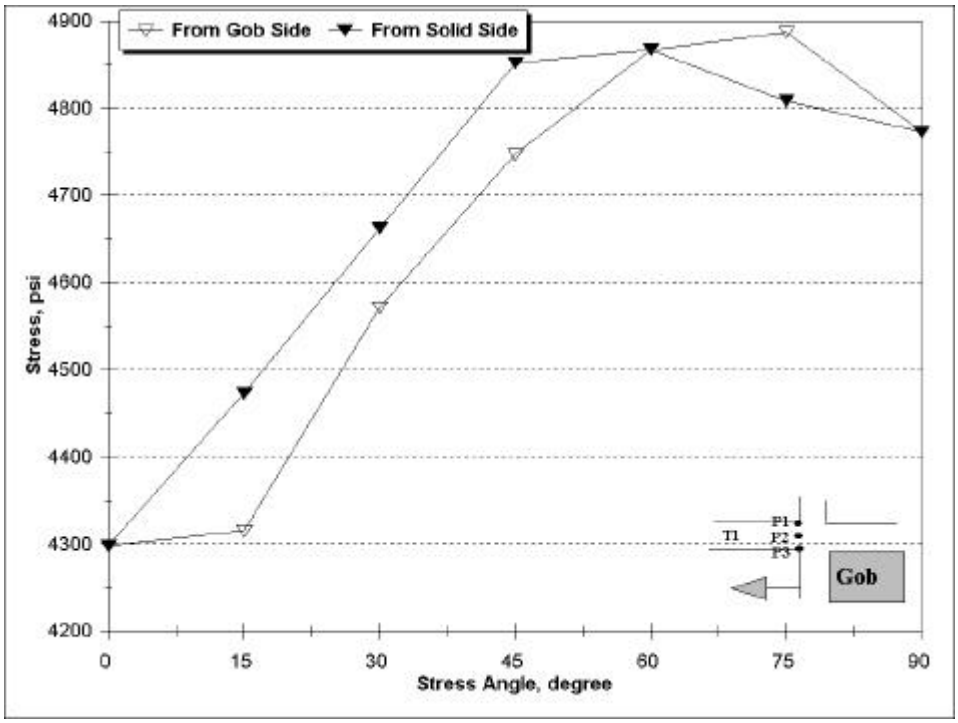


(c) at Points P1 and P3

Fig. 5-34 Von-Mises Stress in Tailgate 1 (σ_{hmax} from Solid Coal Side)



(a) at Point P1



(b) at Point P3

Fig. 5-35 Comparison of Von-Mises Stress in Tailgate 1

5.4.2 Max. Principal Stress in Headgate and Tailgate

Max. Principal Stress in Headgate

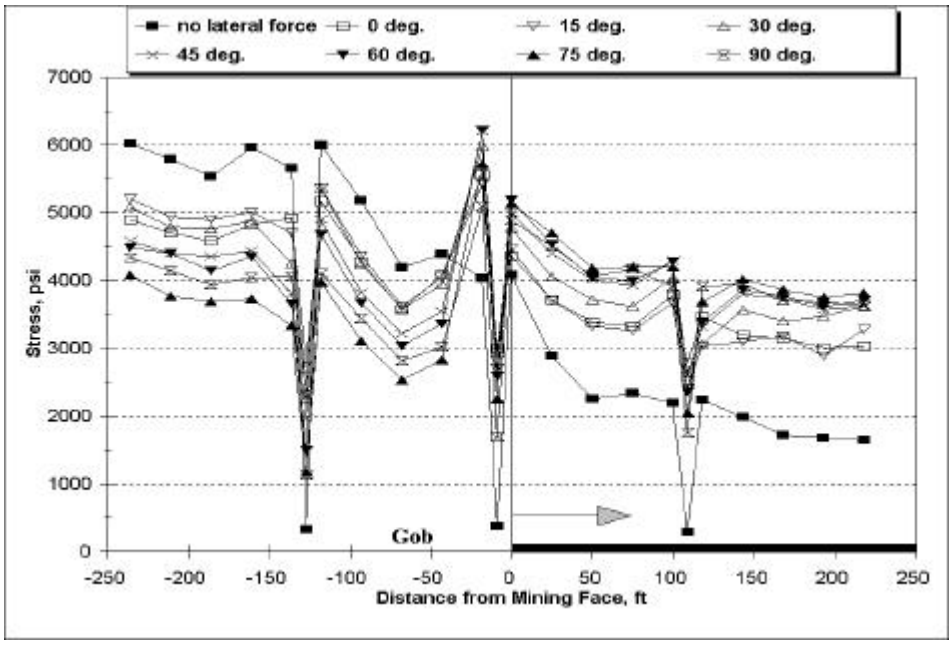
Generally, the maximum principal stress is distributed in the similar way as the Von-Mises stress. It is concentrated along the entry rib sides. At the entry center, the stress is smaller.

The maximum principal stress at the roof line level in the headgate is shown in Fig. 5-36, when the maximum horizontal stress is from the gob side. It indicates that the maximum principal stress at the T-junction is the largest. The principal stress subject to horizontal stress is larger than that without the horizontal stress. In addition, the principal stress generally increases with the stress angle.

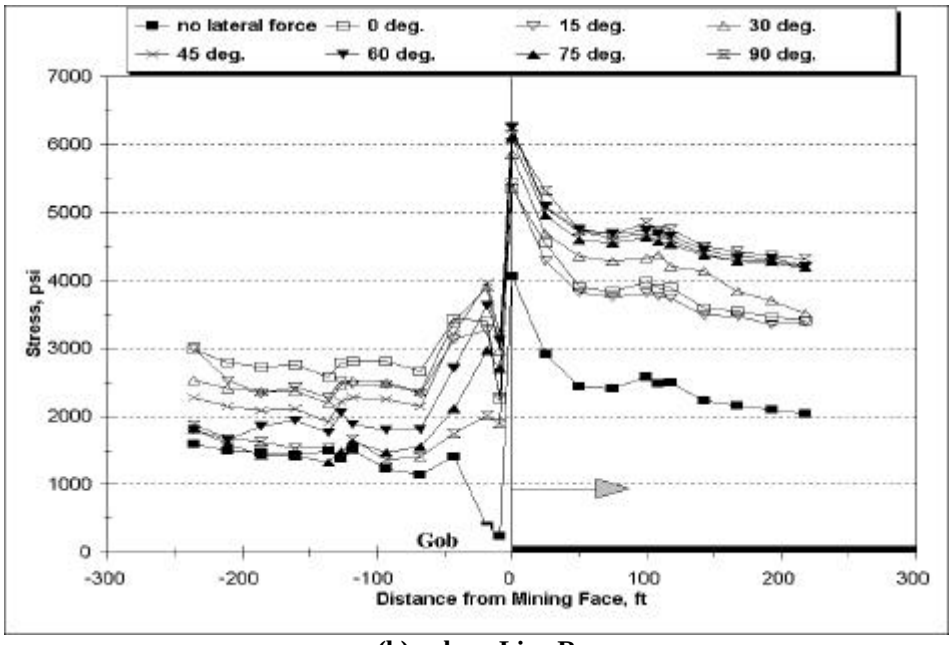
At the T-junction, the maximum principal stress at point P1 increases with the stress angle from 0^0 to 60^0, and then decreases slightly from 60^0 to 90^0. At point P3, the stress increases with the stress angle from 0^0 to 45^0, and then changes slightly with the angle, as shown in Fig. 5-37(a). The maximum principal stress at point P3 is larger than that at point P1.

When the maximum horizontal stress is from the solid coal side, the maximum principal stress in the headgate is similar to that from the gob side. At the T-junction, the principal stress at point P1 increases slightly with the stress angle from 0^0 to 90^0 while at point P3, the stress also increases with the stress angle from 0^0 to 90^0, as shown in Fig. 5-37(b). The maximum principal stress at point P3 is also larger than that at point P1.

The maximum principal stress at the T-junction is shown in Fig. 5-38 when the maximum horizontal stress is from the gob side and from the solid coal side. In the headgate, the stress in the roof of the T-junction is larger when the horizontal stress is from the gob side. The difference of the maximum principal stress between these two loading conditions is significant, especially at point P1, in which the headgate will be in the worst stress condition.

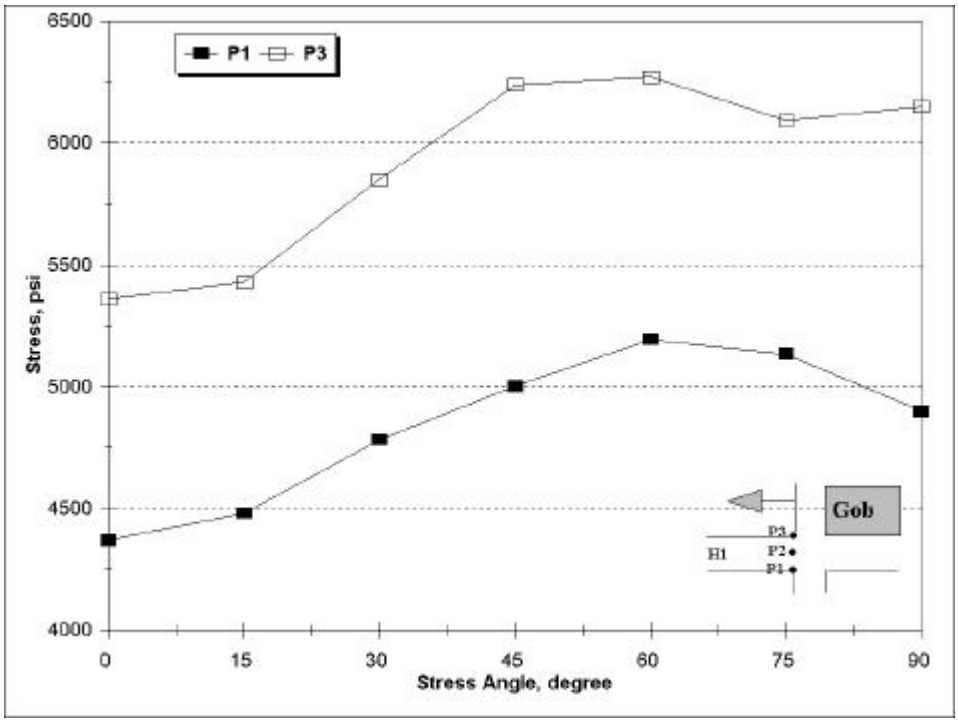


(a) along Line L

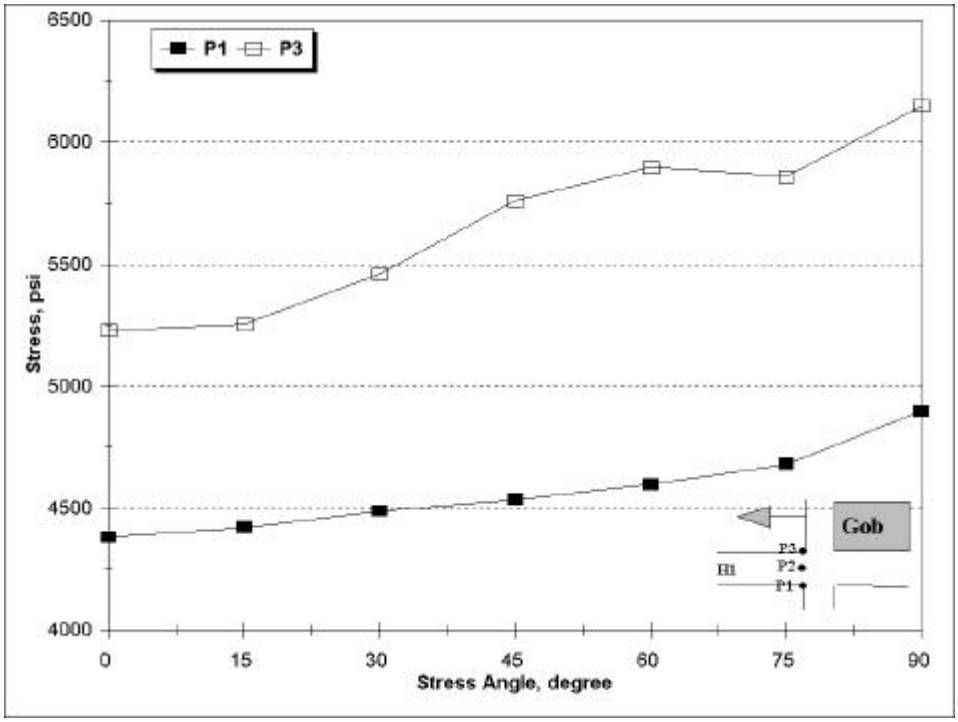


(b) along Line R

Fig. 5-36 Max. Principal Stress in Headgate 1 (σ_{hmax} from Gob Side)

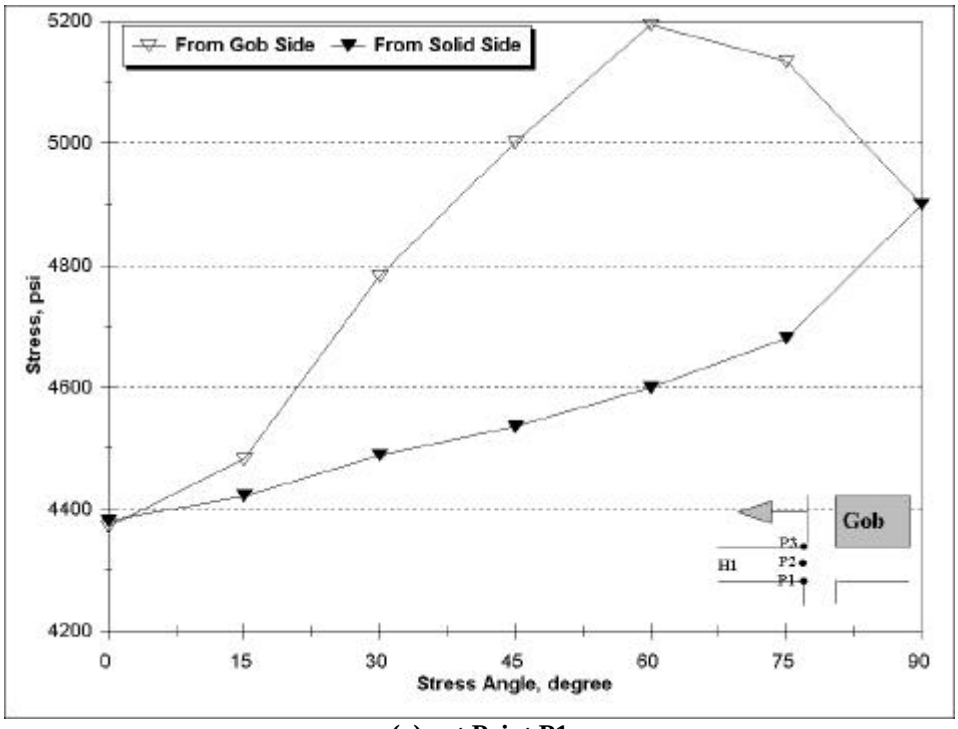


(a) σ_{hmax} from Gob Side

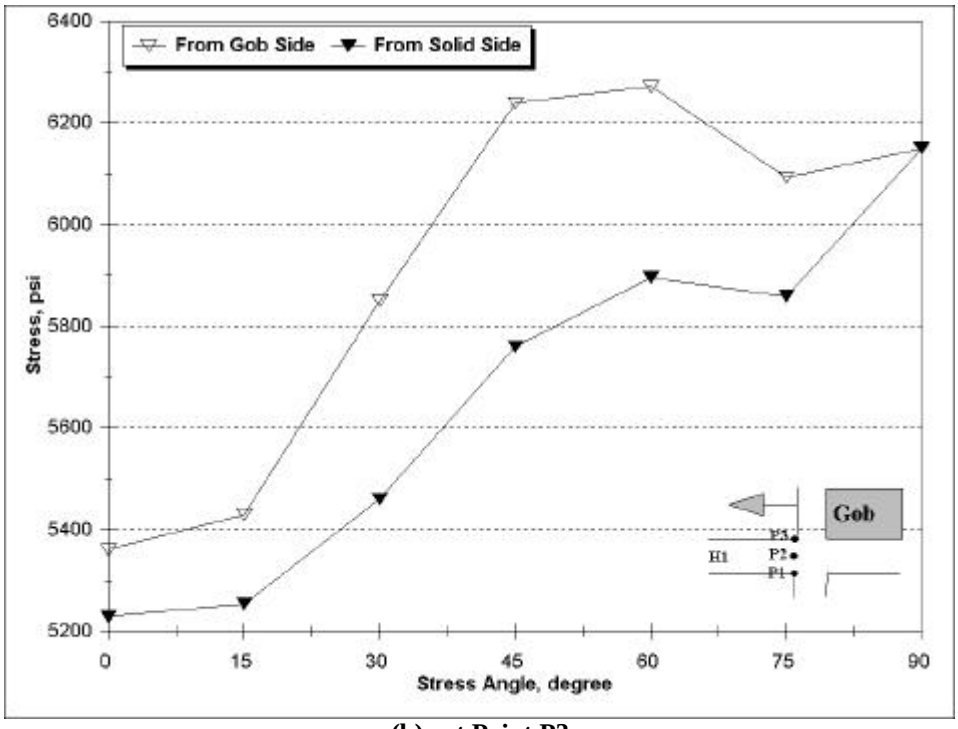


(b) σ_{hmax} from Gob Side

Fig. 5-37 Max. Principal Stress in Headgate 1



(a) at Point P1



(b) at Point P3

Fig. 5-38 Comparison of Max. Principal Stress in Headgate 1

Max. Principal Stress in Tailgate

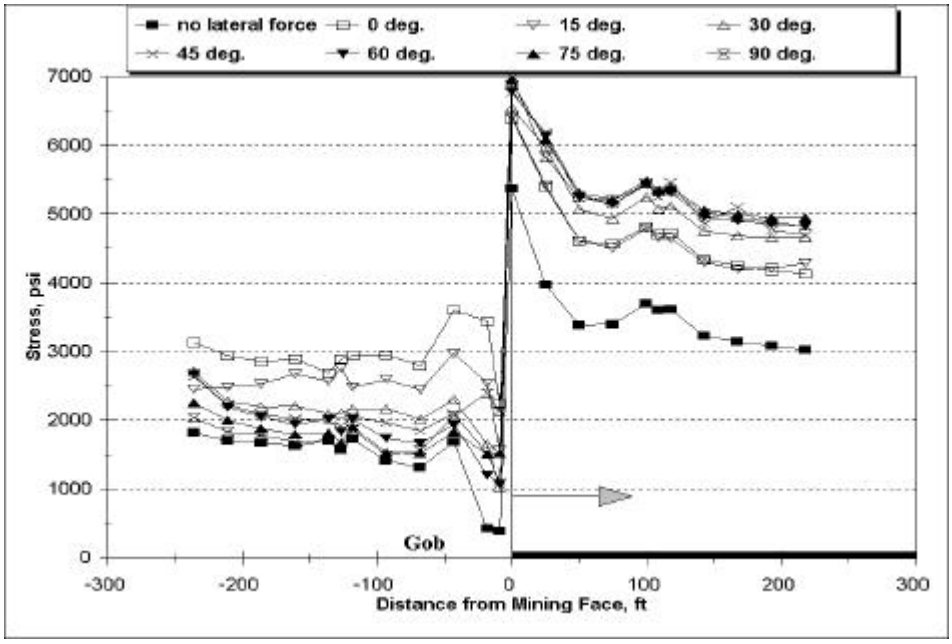
The maximum principal stress in the tailgate is distributed in the similar way as that in the headgate. It is concentrated along the entry rib sides. At the entry center, the stress is smaller.

The maximum principal stress at the roof line level in the tailgate is shown in Fig. 5-39, when the maximum horizontal stress is from the gob side. It indicates that the maximum principal stress at the T-junction is the largest. The principal stress subject to horizontal stress is larger than that without the horizontal stress. In addition, the principal stress generally increases with the stress angle.

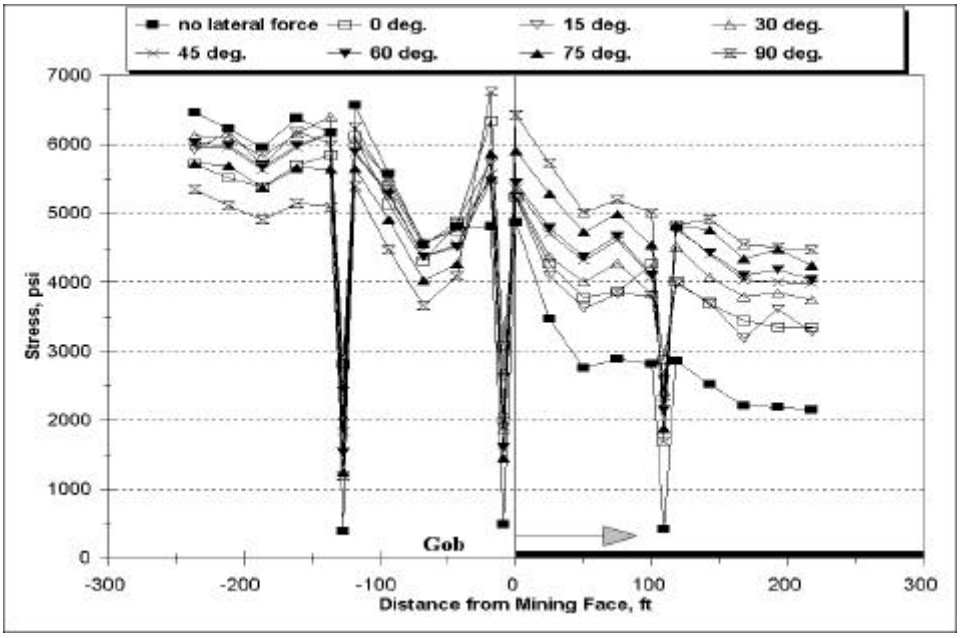
At the T-junction, the maximum principal stress at point P1 increases with the stress angle from 0^0 to 90^0. But, when the stress angle is less than 60^0, the stress change is not large, as shown in Fig. 5-40(a). At point P3, the stress also increases with the stress angle from 0^0 to 90^0 gradually. The maximum principal stress at point P3 is larger than that at point P1.

When the maximum horizontal stress is from the solid coal side, the maximum principal stress in the tailgate is similar to that from the gob side. At the T-junction, the principal stress at point P1 increases rapidly with the stress angle from 0^0 to 45^0, and then increase slightly from 45^0 to 90^0, as shown in Fig. 5-40(b). At point P3, the stress also increases with the stress angle from 0^0 to 30^0, and then stays nearly unchanged from 30^0 to 90^0. The maximum principal stress at point P3 is also larger than that at point P1.

The maximum principal stress at the T-junction is shown in Fig. 5-41 when the maximum horizontal stress is from the gob side and from the solid coal side. In the taildgate, the stress in the roof of the T-junction is larger when the horizontal stress is from the solid side. The difference of the maximum principal stress between these two loading conditions is significant, especially at point P1. However, the difference is not as larger as that in the headgate.

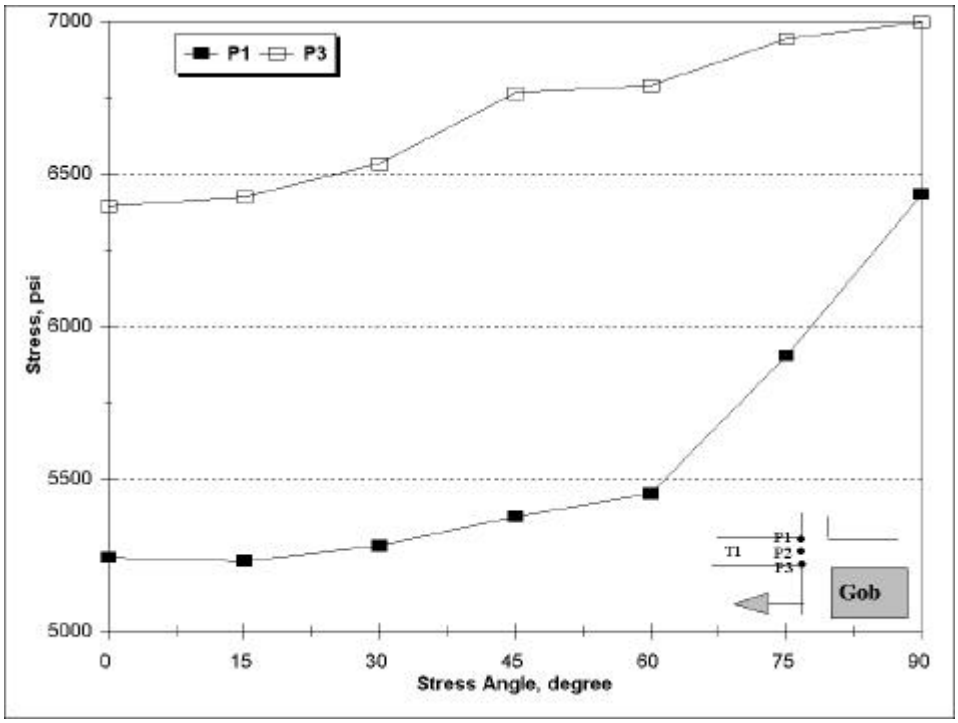


(a) along Line L

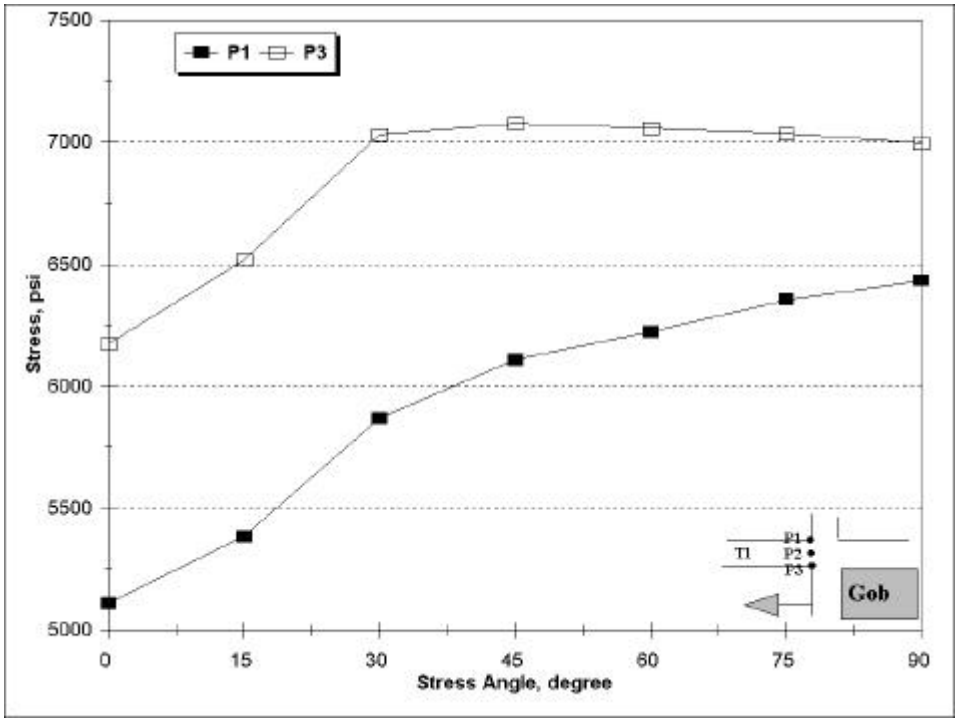


(b) along Line R

Fig. 5-39 Max. Principal Stress in Tailgate 1 (σ_{hmax} from Gob Side)

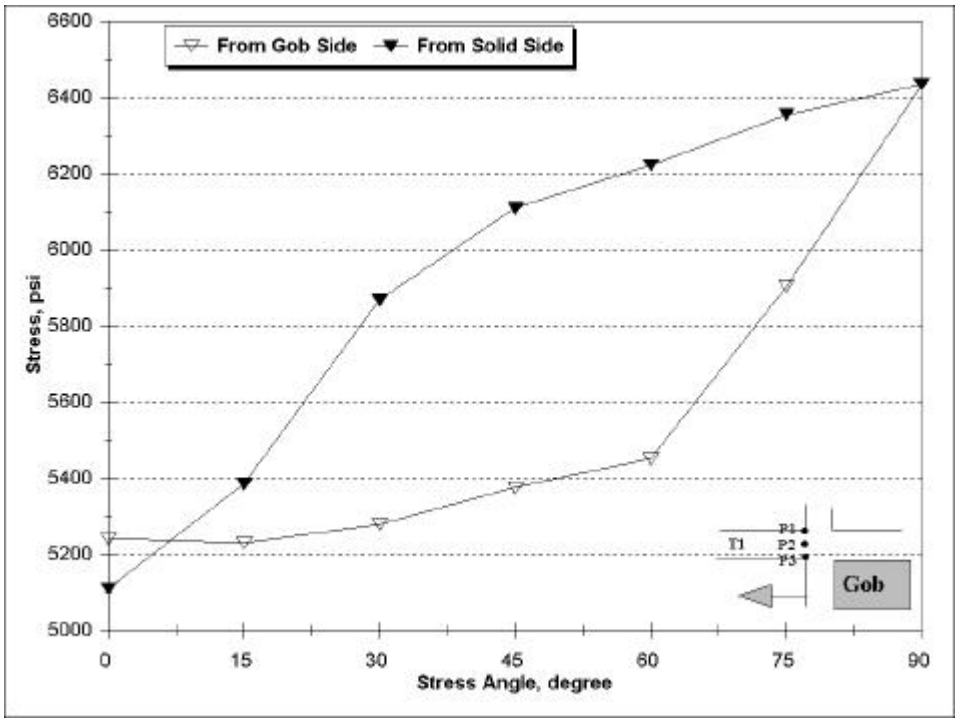


(a) σ_{hmax} from Gob Side

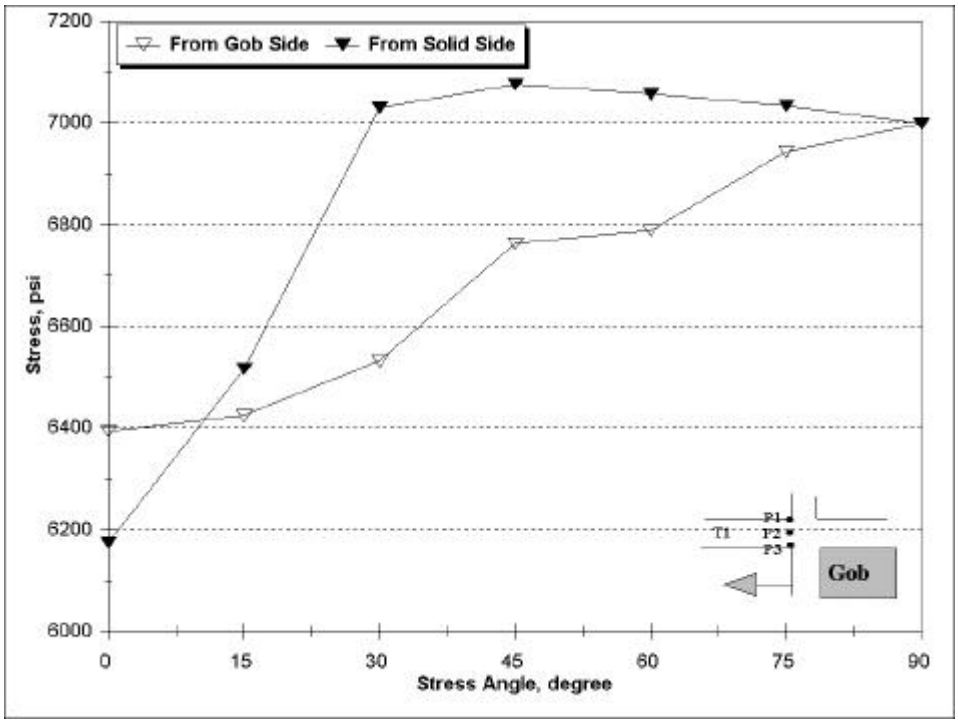


(b) σ_{hmax} from Solid Coal Side

Fig. 5-40 Max. Principal Stress in Tailgate 1



(a) at Point P1



(b) at Point P3

Fig. 5-41 Comparison of Max. Principal Stress in Tailgate 1

5.4.3 Min. Principal Stress in Headgate and Tailgate

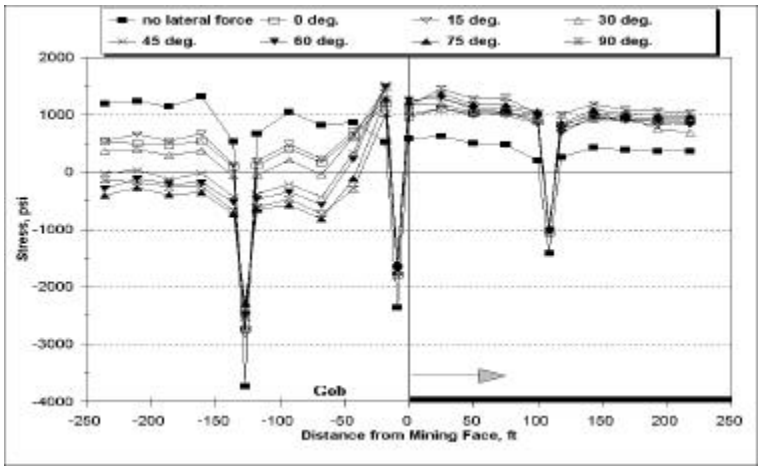
As discussed previously, the minimum principal stress in the entry roof changes with the stress angle slightly. Generally, the stress is smaller at the entry center. Under the high horizontal stress, the minimum principal stress at the entry center increases.

Fig. 5-42 shows the minimum principal stress at the roof line level in the headgate when the maximum principal stress is from the gob side. It indicates that the stress is larger than that without the horizontal stress. But the influence of the stress angle on the minimum principal stress is not as significant as that on the Von-Mises stress and the maximum principal stress.

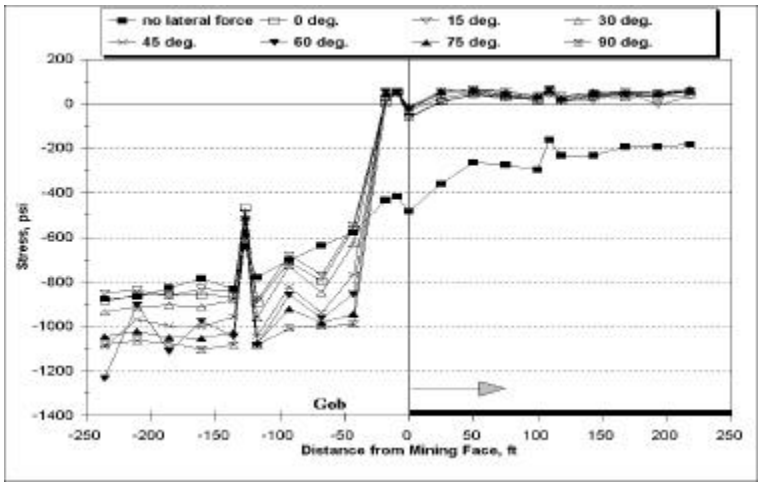
At the T-junction, the minimum principal stress at points P1 and P3 is larger than that at point P2, as shown in Fig. 5-43(a). The stress at point P3 is larger than that at point P3. But the difference is small.

When the maximum principal stress is from solid coal side, the minimum principal stress at points P1~P3 is shown in Fig. 5-43(b). It also indicates that the stress at point P3 is larger than that at point P1.

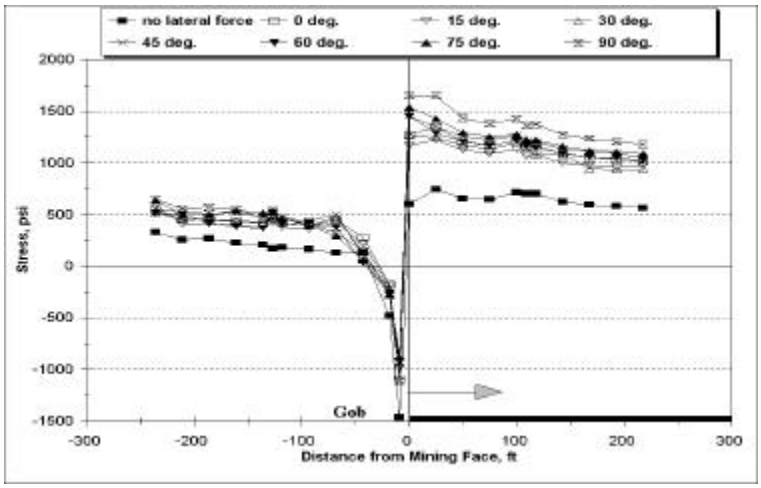
In the tailgate, the minimum principal stress is similar to that in the headgate, as shown in Figs. 5-44 and 5-45. The minimum stress occurs at the entry center (P2). At the T-junction, the minimum principal stress at P3 is always larger than that at point P1, no matter which direction the maximum horizontal stress comes from. In addition, the minimum principal stress changes with the stress angle slightly.



(a) along Line L

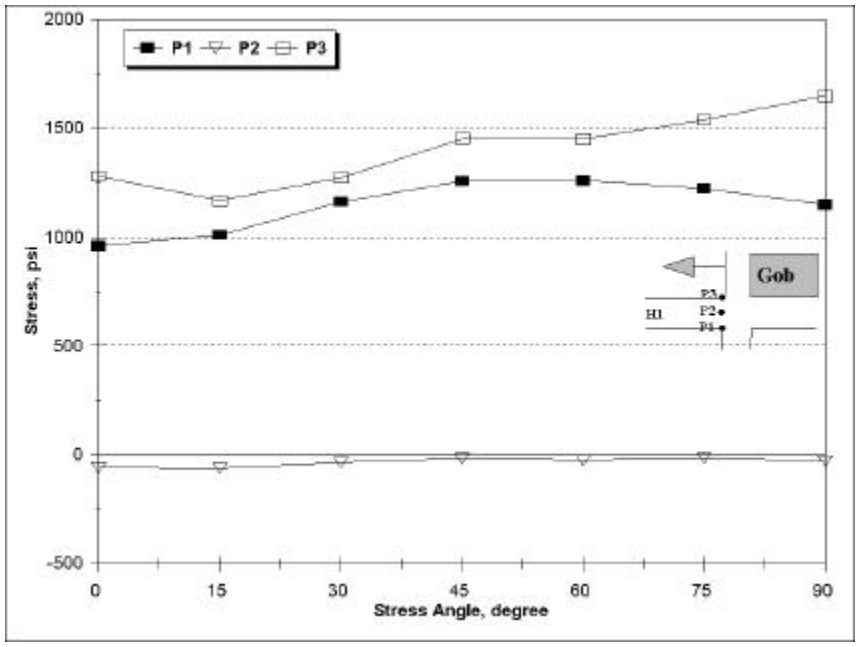


(b) along Line C

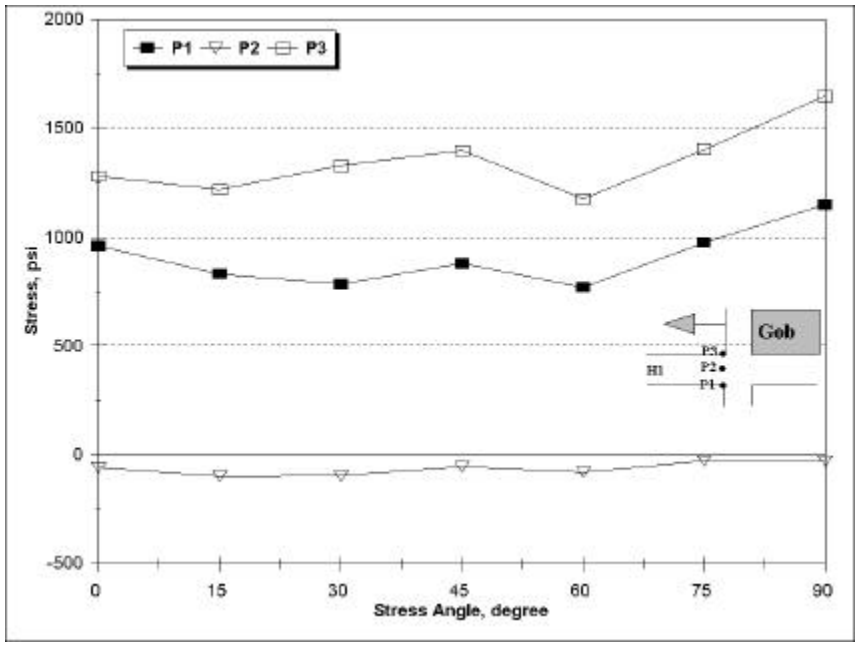


(c) along Line R

Fig. 5-42 Min. Principal Stress in Headgate 1 (σ_{hmax} from Gob Side)

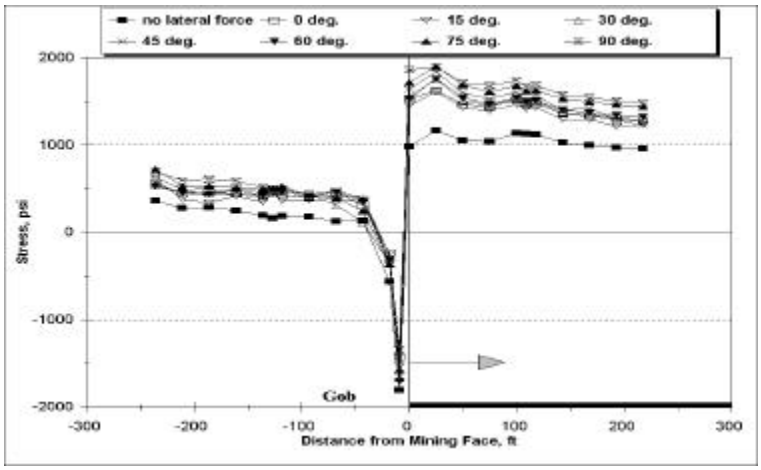


(a) σ_{hmax} from Gob Side

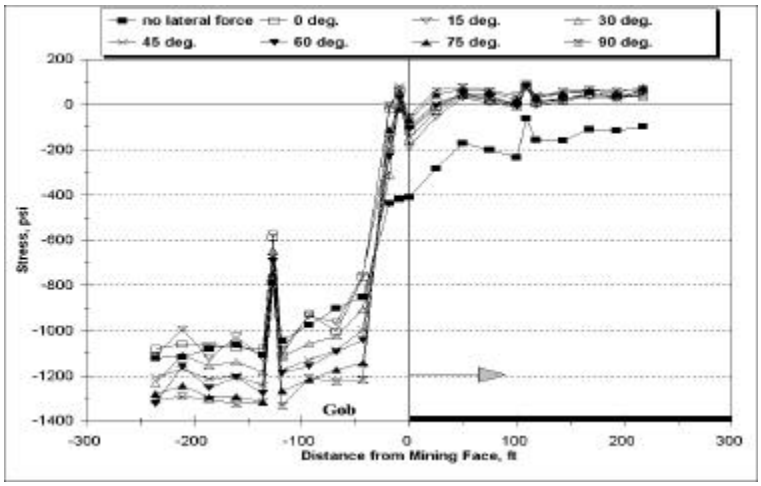


(b) σ_{hmax} from Solid Coal Side

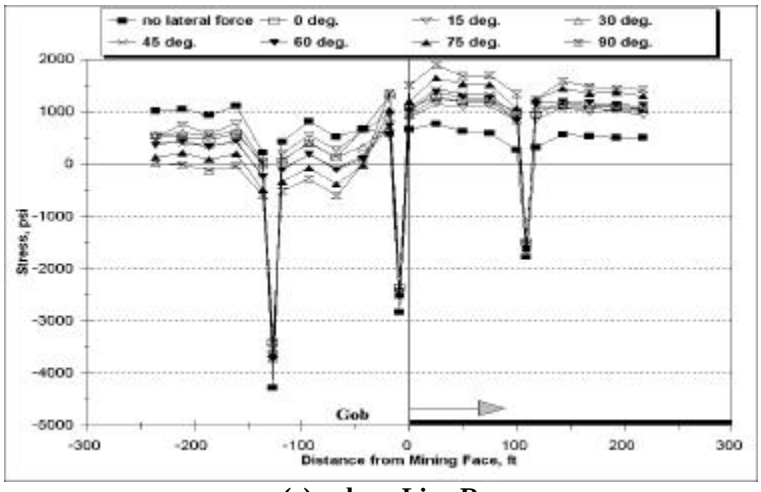
Fig. 5-43 Min. Principal Stress in Headgate 1



(a) along Line L

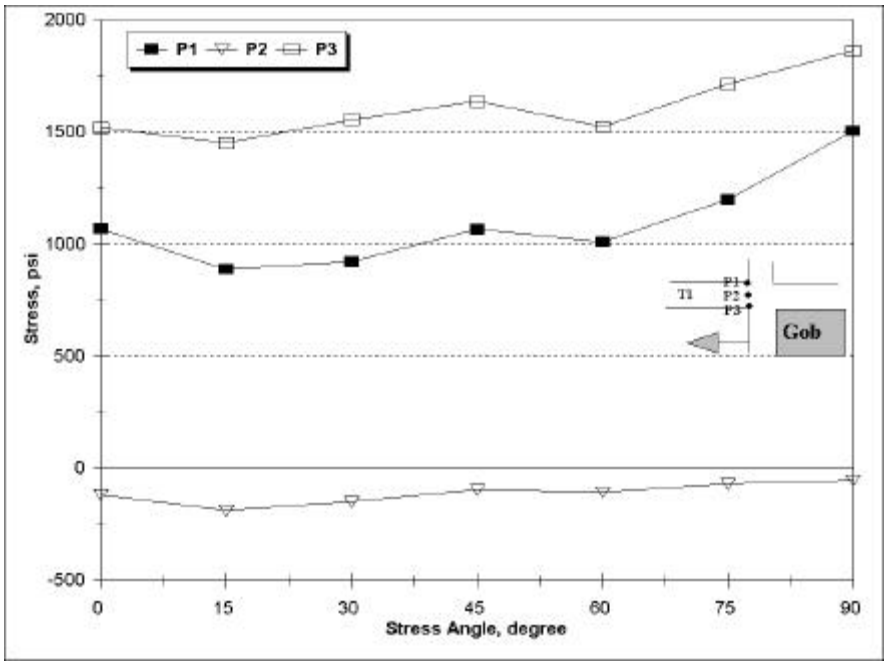


(b) along Line C

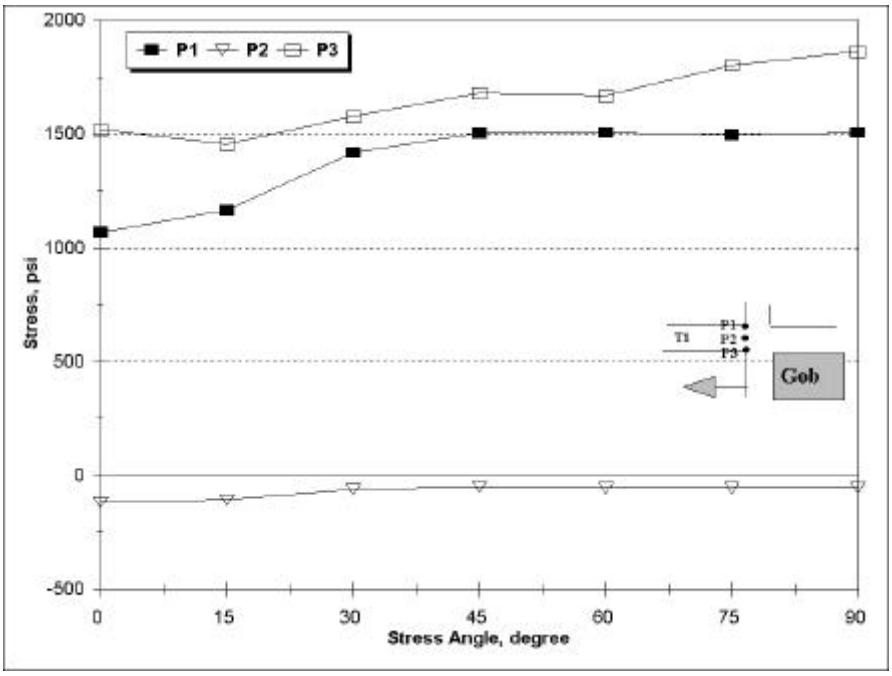


(c) along Line R

Fig. 5-44 Min. Principal Stress in Tailgate 1 (σ_{hmax} from Gob Side)



(a) σ_{hmax} from Gob Side



(b) σ_{hmax} from Solid Coal Side

Fig. 5-45 Min. Principal Stress in Tailgate 1

5.4.4 Comparison of Stress between Headgate and Tailgate

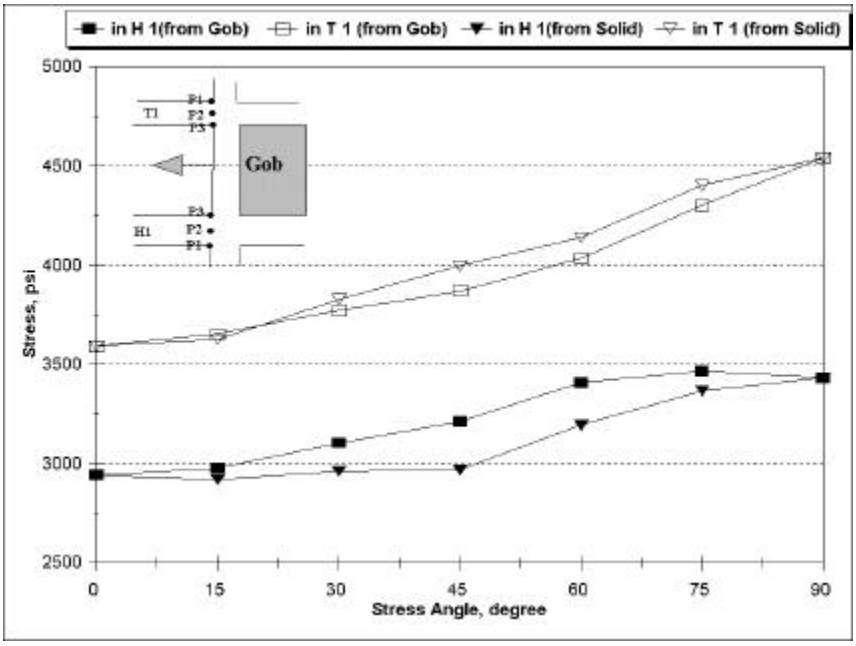
Because of the gob effects, the stress distributions in the headgate and the tailgate are different. In the following, the stress differences at the two T-junctions are analyzed.

Fig. 5-46 shows the Von-Mises stress at the two T-junctions. It indicates that the Von-Mises stress in the tailgate is always larger than that in the headgate, no matter which direction the maximum horizontal stress comes from. At point P1, the Von-Mises stress in the headgate and the tailgate generally increases with the stress angle from 0^0 to 90^0. At point P3, the Von-Mises stress in the headgate and the tailgate increases with the stress angle from 0^0 to 60^0, and then decreases slightly from 60^0 to 90^0. Generally, the difference of stress between in the headgate and in the tailgate is about 500 psi.

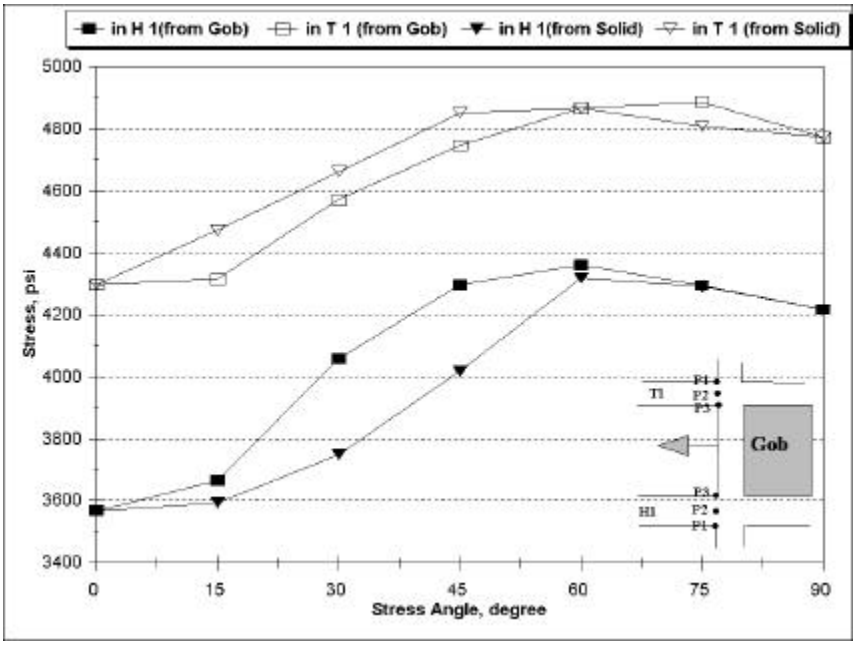
The maximum principal stress at the two T-junction is shown in Fig. 5-47. It also shows that the maximum principal stress in the tailgate is larger than that in the headgate, no matter which direction the maximum horizontal stress comes from. Generally, when the horizontal stress is from the gob side, the stress in the headgate is distributed in the similar way as the stress in the tailgate when the horizontal stress is from the solid coal side.

Some field measurements have found some headgate roof problems. Without the horizontal stress, the headgates are usually less troublesome than tailgates. In a high horizontal field, the headgate roof problems increase. In fact, the tailgate roof problems also increase. In a high horizontal stress field, the stress in the roof is much larger than that without the horizontal stress. In addition, when the maximum horizontal stress is from the gob side, the stress in the headgate is larger than that from the solid side. Maybe this is one of the reasons causing the headgate roof problems.

In short, the stress in the tailgate is larger than that in the headgate. From the stress point of view, the tailgates are in a worse condition than the headgates.

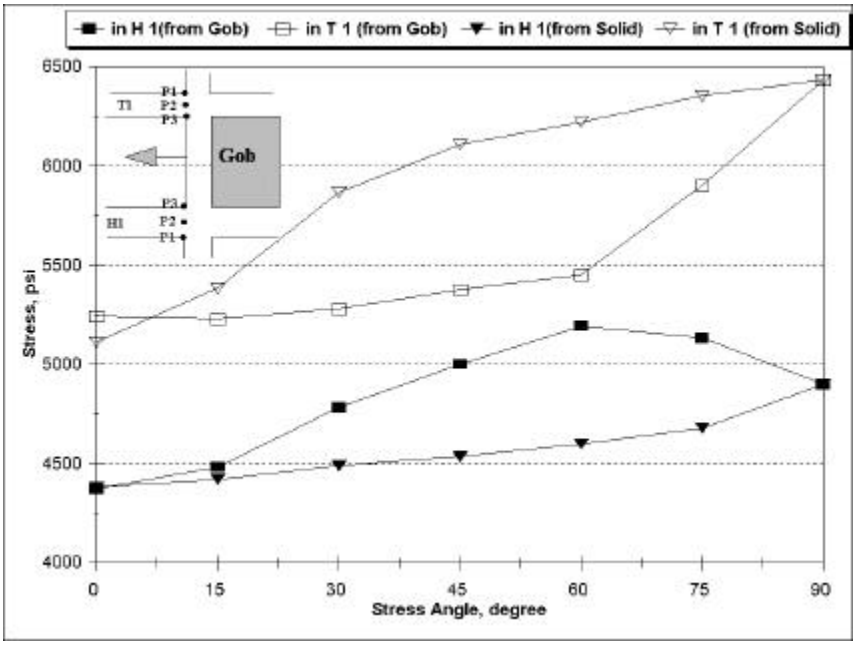


(a) at Point P1

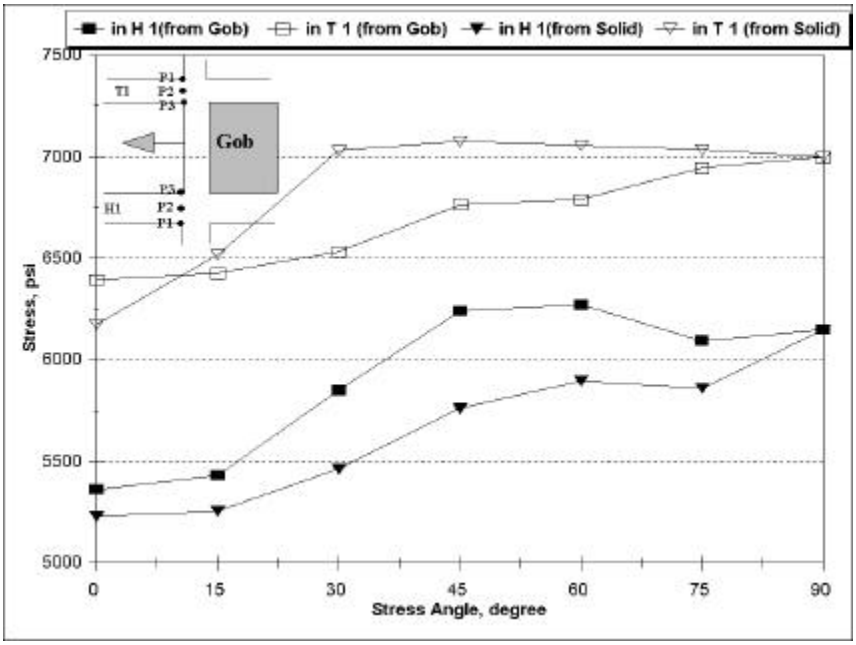


(b) at Point P3

Fig. 5-46 Comparison of Von-Mises Stress Between Headgate and Tailgate



(a) at Point P1



(b) at Point P3

Fig. 5-47 Comparison of Max. Principal Stress Between Headgate and Tailgate

5.5 Discussion of Results

Based on the above stress analysis, it is confirmed that the stress at the roof line level in the headgates and the tailgates subject to high horizontal stress is distributed in the different way from that without the horizontal stress. In a longwall panel, the entries in the front abutment zone will easily experience some roof problems. Without a horizontal stress, the front abutment pressure usually is very large. When a high horizontal stress exists, the stress in the zone increases further, which worsens the roof conditions.

Generally, the stresses at the T-junctions of a longwall panel are distributed in the following ways:

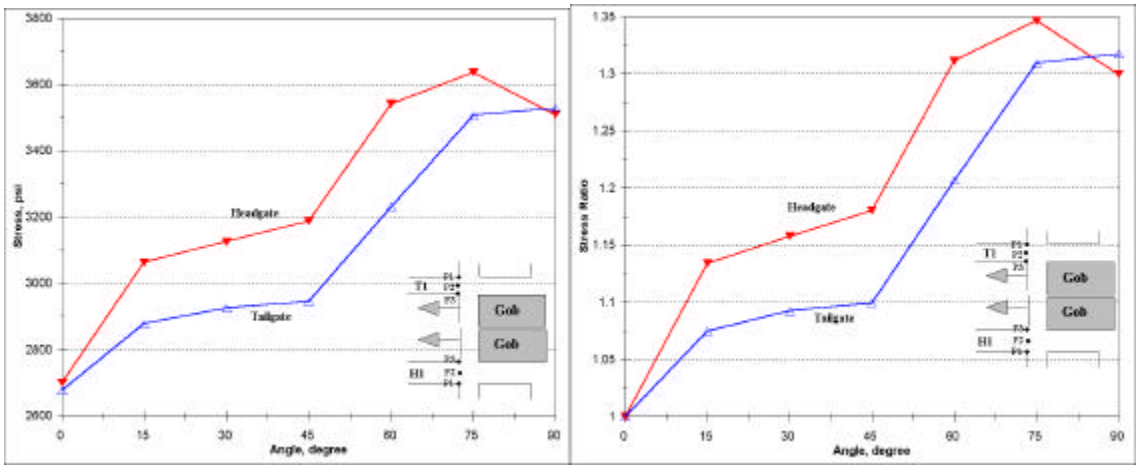
A. Single panel mining

(1) The Von-Mises stress at the T-junctions increases with the stress angle between the maximum horizontal stress and the mining direction. Generally, the T-junctions are in the worst stress conditions when the stress angle is equal to or more than 60^0. At point P1, the Von-Mises stress increases with the stress angle from 0^0 to 90^0, as shown in Fig. 5-20(a). At Point P3 (the corner of the longwall mining face), the Von-Mises stress increases with the stress angle from 0^0 to 60^0, and then decreases from 60^0 to 90^0.

(2) The maximum principal stress distribution at the T-junctions in a single panel is similar to the Von-Mises stress. The maximum principal stress at point 1 increases with the stress angle from 0^0 to 90^0. At point 3, it reaches the maximum when the stress angle is about 60^0.

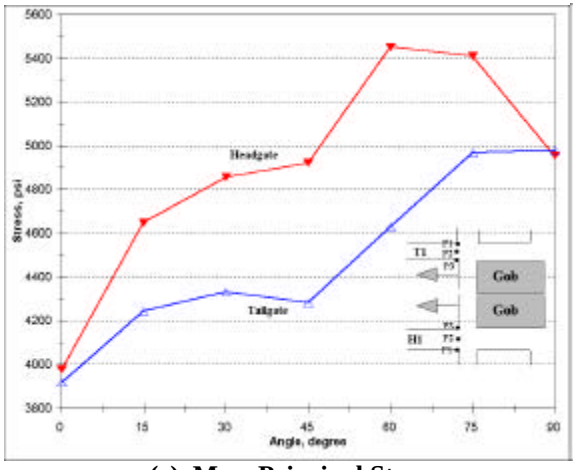
(3) When the maximum horizontal stress is from the headgate side, the stresses, such as the Von-Mises stress and the maximum principal stress, at the T-junction in the headgate is larger than that in the tailgate, as shown in Fig. 5-20.

The typical stress distributions at the T-junctions in a single panel are shown in Figs. 5-48 and 5-49.

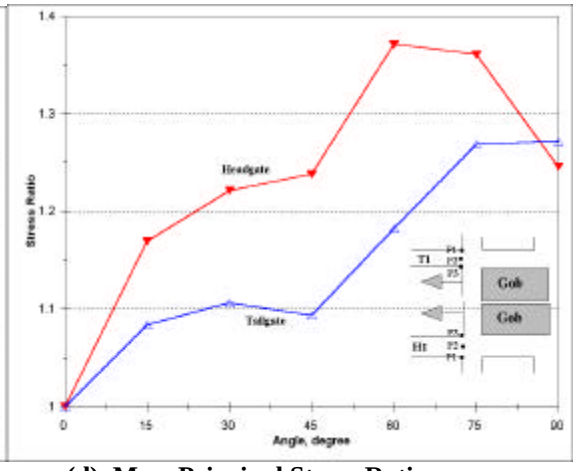


(a) Von-Mises Stress

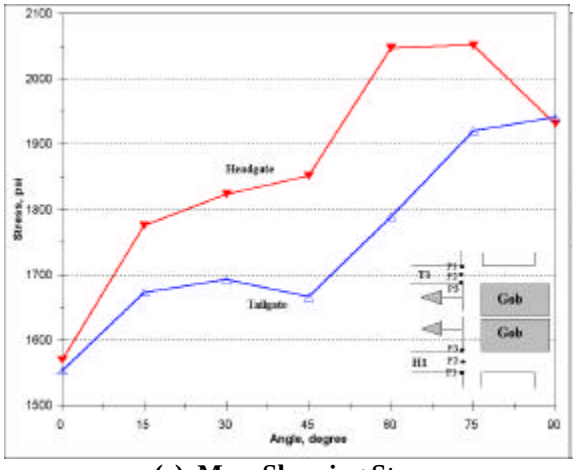
(b) Von-Mises Stress Ratio



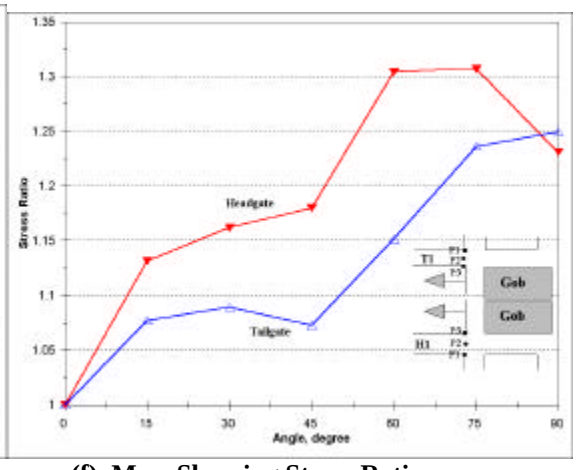
(c) Max. Principal Stress



(d) Max. Principal Stress Ratio

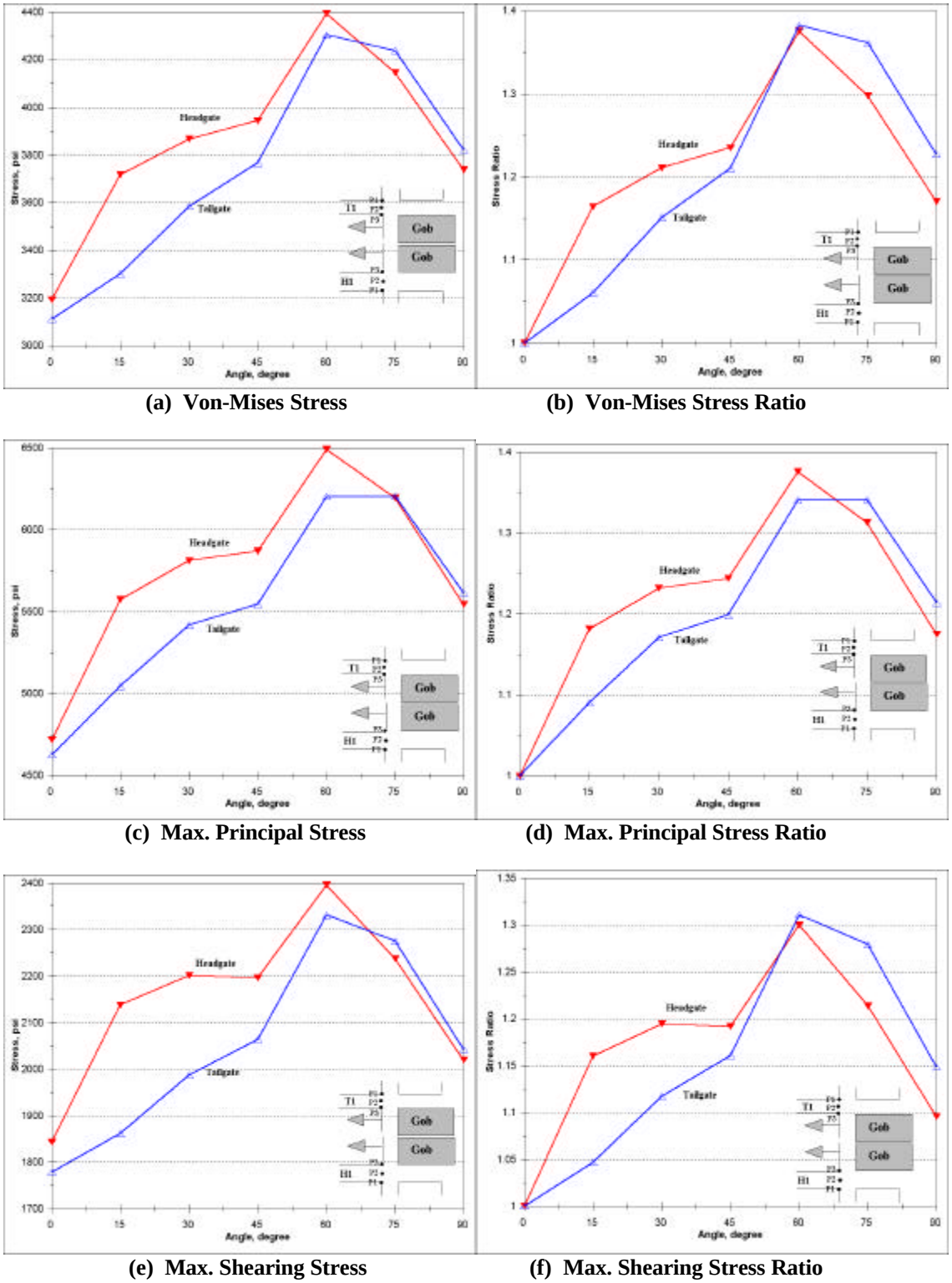


(e) Max. Shearing Stress



(f) Max. Shearing Stress Ratio

Fig. 5-48 Typical Stress Distributions at T-Junctions (Point P1 – Single Panel)



(a) Von-Mises Stress **(b) Von-Mises Stress Ratio**

(c) Max. Principal Stress **(d) Max. Principal Stress Ratio**

(e) Max. Shearing Stress **(f) Max. Shearing Stress Ratio**

Fig. 5-49 Typical Stress Distributions at T-Junctions (Point P3 – Single Panel)

B. Multiple panel mining

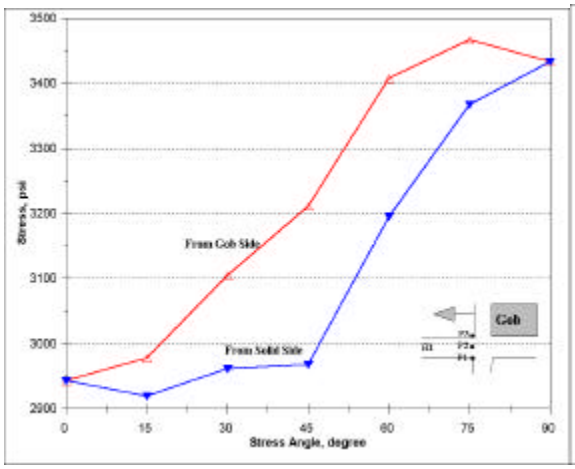
(1) The tailgate entries in the current mining panel will be heavily affected by the adjacent mined-out panel. Since the tailgate entries are subjected to the side abutment pressure caused by the mined-out panel, the tailgate entries are generally in the worst conditions. The stresses in the headgate entries are smaller than those in a single panel (comparing Fig. 5-20(a)~(d) with Figs. 5-47(a)~(b)). Therefore, the headgate entries are in a better condition as compared to the tailgate entries.

(2) The stress angle between the maximum horizontal stress and mining direction also has a significant effect on the entry roof stability in a multiple-panel system. However, the entries in a multiple-panel system are less sensitive to the stress angle than those in a single panel. In a single panel, the stress increases with the stress angle rapidly, especially when the angle is less than 60^0. But in a multiple-panel system, the stress increases with the stress angle gradually.

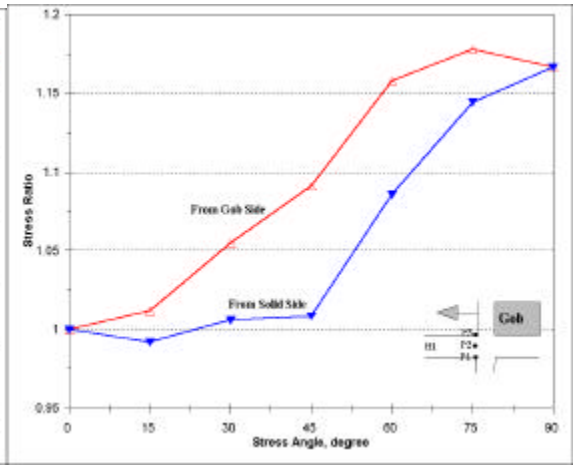
(3) The direction of the maximum horizontal stress has some effects on the stresses in the entry roof. When the horizontal stress is from the gob side (the mined-out panel side), the stress at the T-junction in the headgate is larger than that from the solid coal side. For the tailgate entries, it reverses.

(4) The influence of the stress angle on the minimum principal stress in the roof is small. Generally, the minimum principal stress in the roof occurs at the entry center and increases under the high horizontal stress.

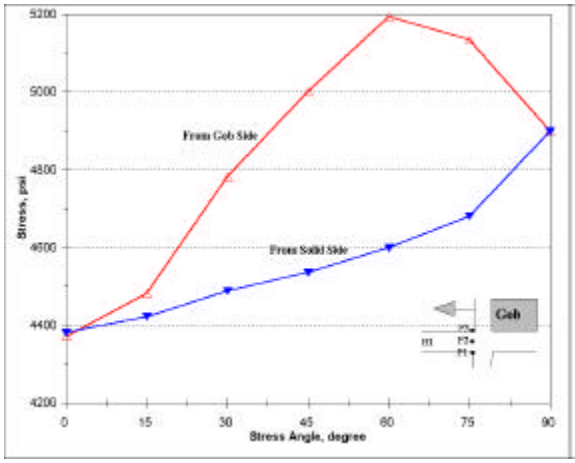
The typical stress distributions at the headgate T-junction are shown in Figs. 5-50 and 5-51. They indicate that the shear stress increases with the angle from 0^0~60^0(or 75^0), and then decreases slightly from 60^0(or 75^0)~90^0. Generally, the headgate entry is in the worst stress condition when the stress angle is about 60^0~90^0. In addition, when the stress angle changes from 0^0 to 90^0, the roof stress at the T-junction increases about 20%, compared with the stress when the angle is equal to 0^0. Fig. 5-52 shows the Von-Mises stress at the T-junction (from Su and Hasenfus[39]). It is similar to the stress distributions discussed previously.



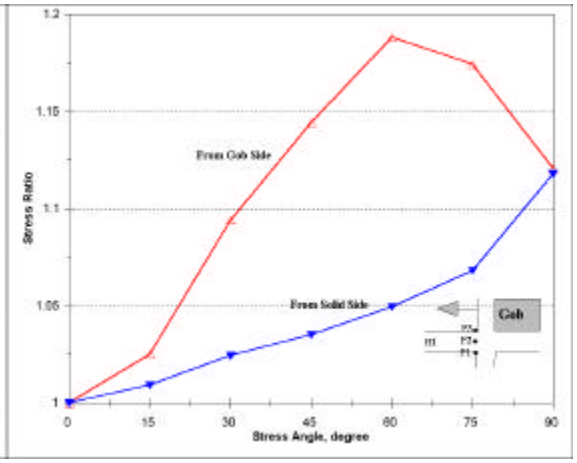
(a) Von-Mises Stress



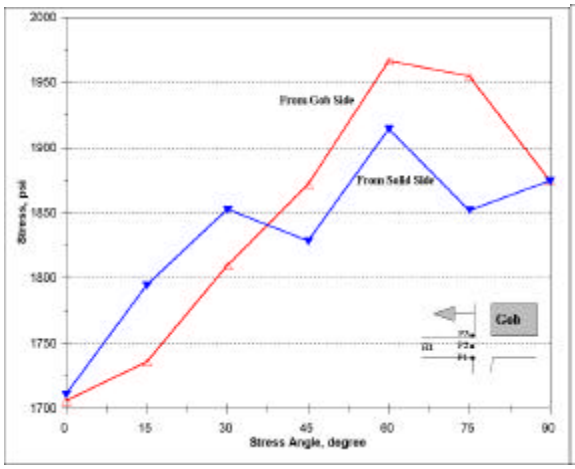
(b) Von-Mises Stress Ratio



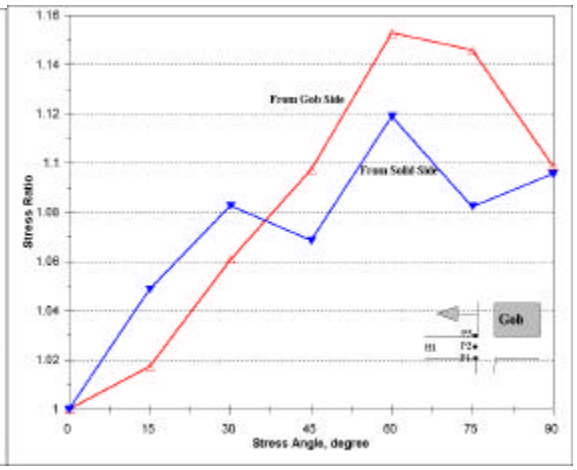
(c) Max. Principal Stress



(d) Max. Principal Stress Ratio

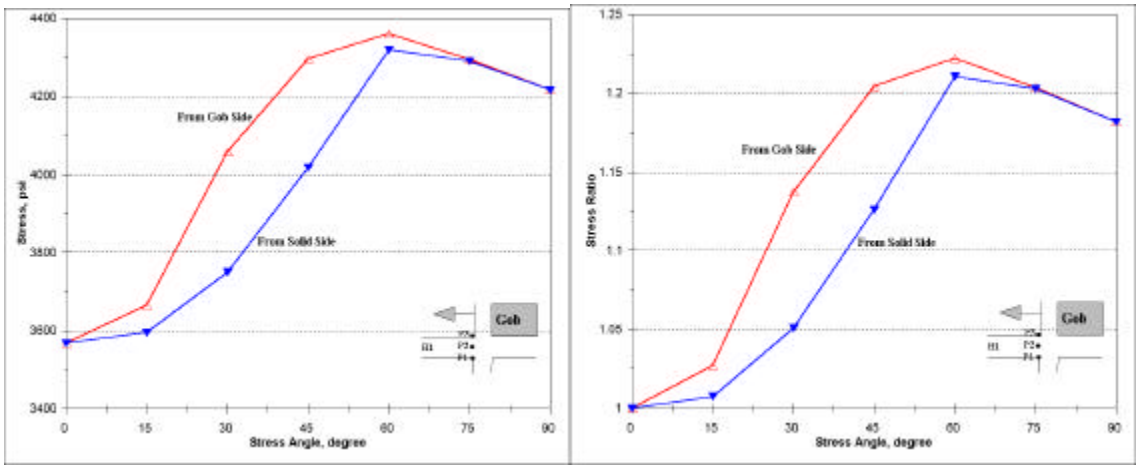


(e) Max. Shearing Stress

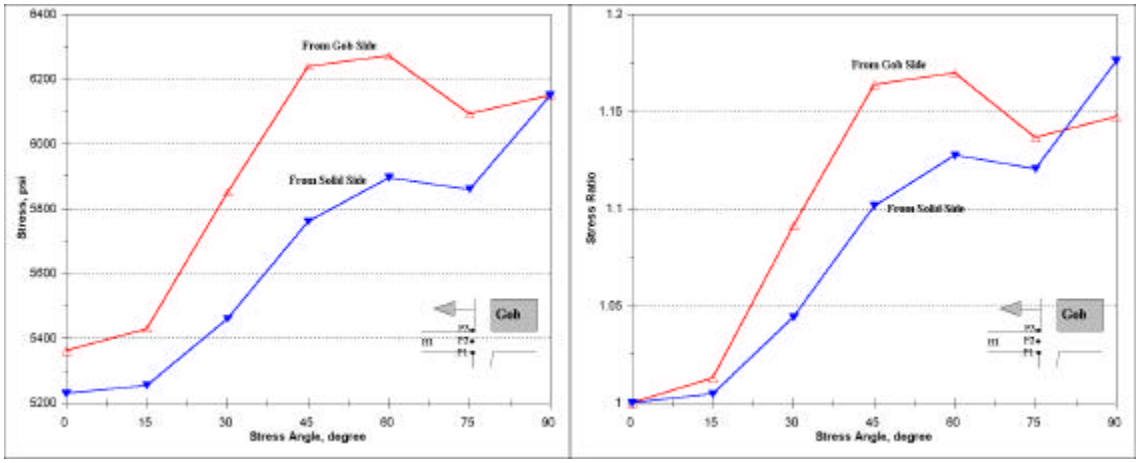


(f) Max. Shearing Stress Ratio

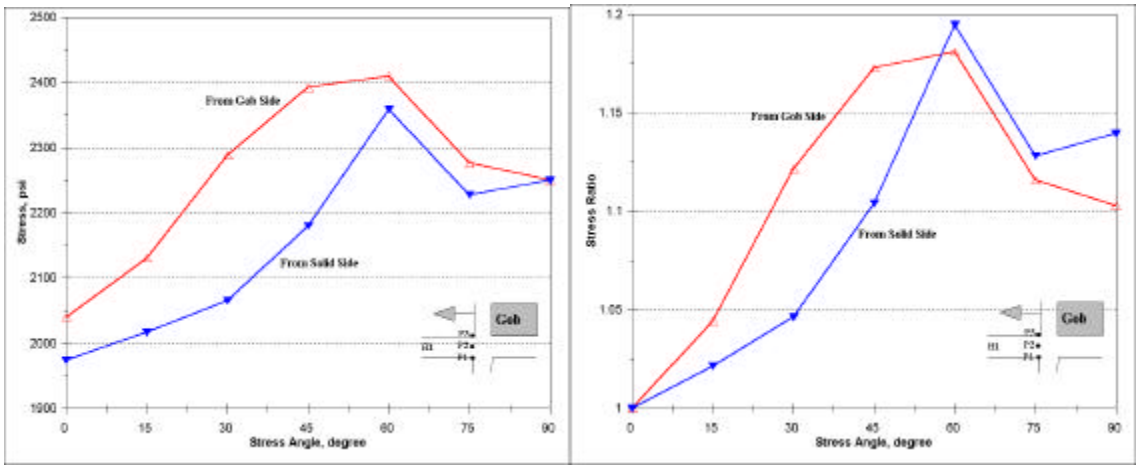
Fig. 5-50 Typical Stress Distributions at Headgate T-Junction (Point P1 – Multiple Panels)



(a) Von-Mises Stress **(b) Von-Mises Ratio**



(c) Max. Principal Stress **(d) Max. Principal Stress Ratio**



(e) Max. Shearing Stress **(f) Max. Shearing Stress Ratio**

Fig. 5-51 Typical Stress Distributions at Headgate T-Junction (Point P3 – Multiple Panels)

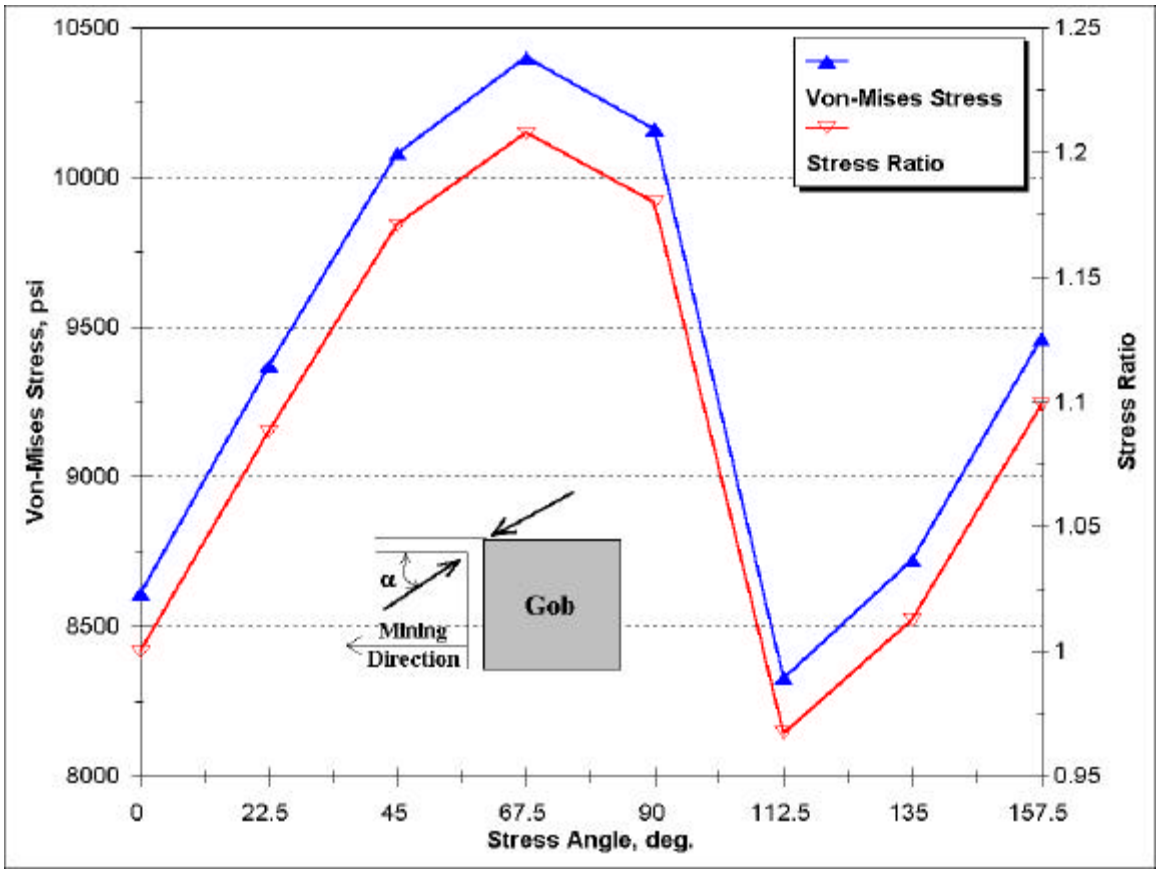


Fig. 5-52 Von-Mises Stress Distributions at Headgate T-Junction (Su and Hasenfus, 1995)