

Figure 11 t=4.0s

The concrete of pile top failed totally at 0.69s and the piles lost the capacity to resist the gravity of the superstructure. As a result, the columns and girder fell and the barge was pounded by the falling columns at 7.6s. Subsequently, the barge was pushed into the river by the falling columns and girders, as shown in Figure 12.

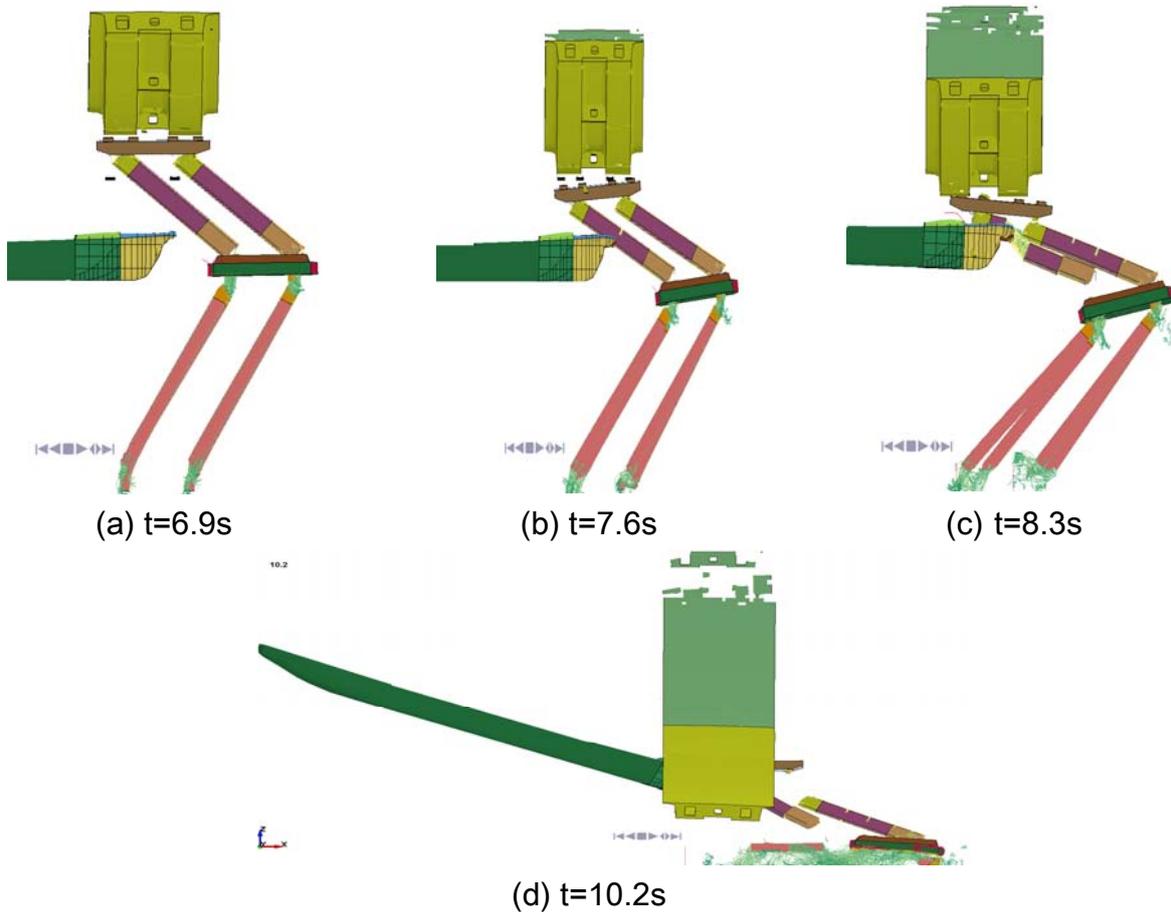


Figure 12 The collapse of pier 23

#### 4.2 Progressive collapse of adjacent spans

Figure 13 illustrates the complete collapse process from the simulation. When Pier 23 collapsed after 0.69s, girder 1 and girder 2 fell into the river subsequently, as shown in Figure 13(b). Then girder 1 and girder 2 broke when girder 1 struck the river bed. Afterward, the suspended girder 2 rotated around the top of pier 24 until it struck pier 24, as shown in Figure 13(c). Next pier 24 also collapsed by the hit of girder 2 and led to the falling of girder 3 (Figure 13(d)). Then pier 25 collapsed as the same manner of pier 24. Consequently, girder 4 fell without the support of pier 25 and rotated around the top of pier 26 (Figure 13(e)). Finally, girder 4 didn't strike pier 26 because the higher river bed between pier 25 and 26 prevented girder 4 from rotating after striking the river bed, as shown in Figure 13 (f).

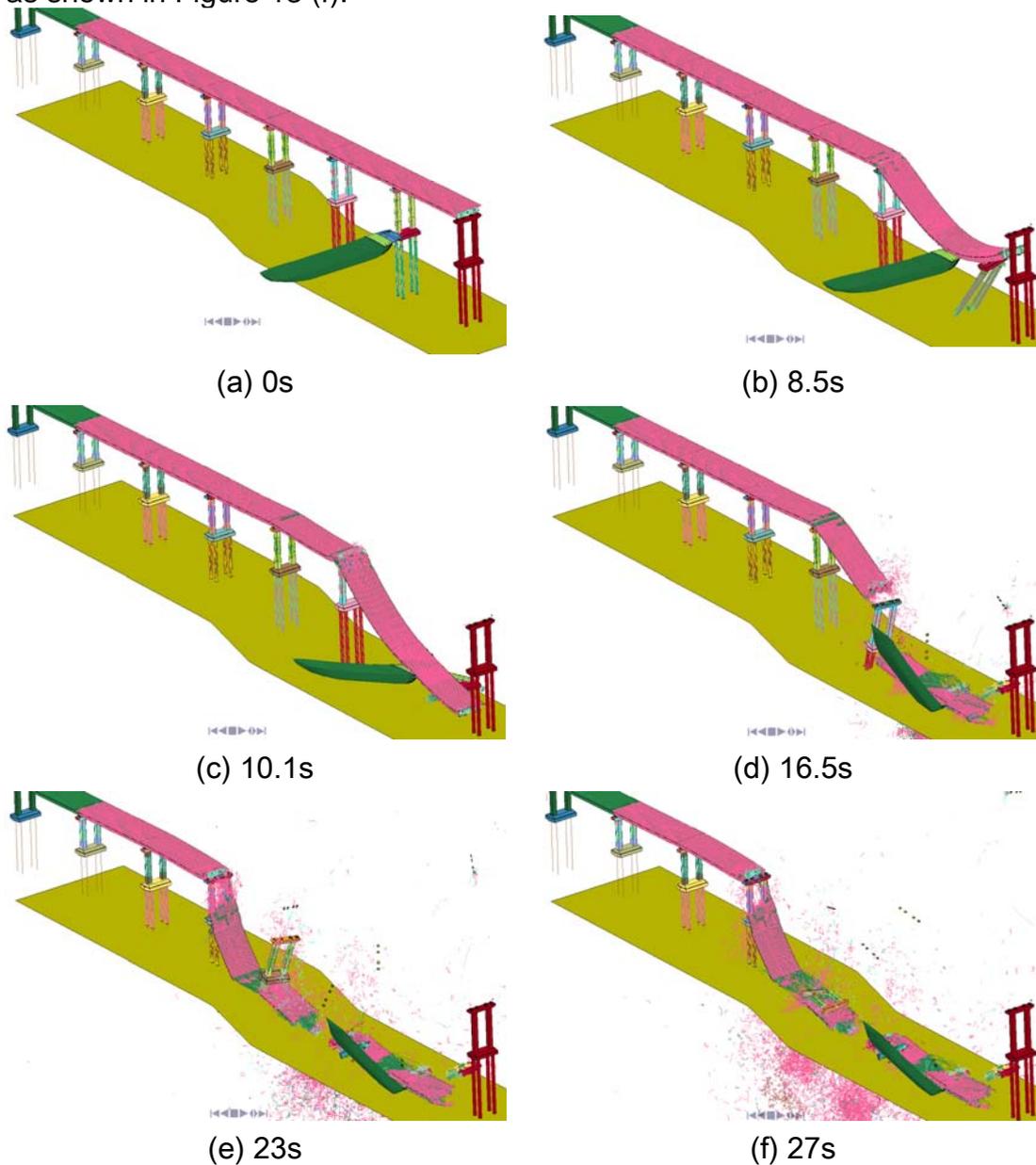


Figure 13 Collapse process of the entire bridge

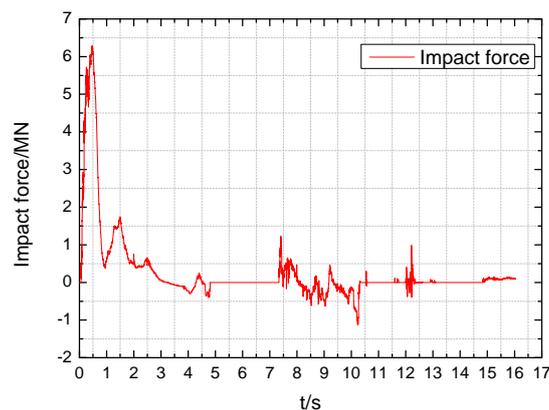


Figure 14 Impact force time history

Figure 14 illustrates the impact force time history of the barge. It shows that the impact force reached the peak value at 0.4s when the damage was slight. The impact force decreased rapidly because the damage became much heavier after 0.4s. After 4.0s, the barge and pile cap separated and impact force turned to zero. Afterwards, the barge was pounded into the river and the impact force was beyond concerns.

## 5. CONCLUSIONS

First, the collapse of pier 23 was induced by both the impact force and the gravity of the superstructure.

Second, progressive collapse happened after the failure of pier 23. For important bridges, it should be prevented in bridge design and thus engineers should pay much attention about such failure modes.

The simulation reproduced the collapse scene which shows a good agreement with the real collapse process. Therefore, the modeling method in the paper is reasonable and thus can provide instructions to other impact simulations.

## 6. Acknowledgement

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