Figure S1: Snapshots of the TC4-0.0 at time intervals of (**a**) t=0.4 s, (**b**) t=0.8 s, (**c**) t=1.2 s, (**d**) t=1.6 s, (**e**) t=2.0 s, and (**f**) t=2.4 s. Each subfigure comprises three images: the top is the laboratory TC result, the middle is TC4-N by Amaro et al. [31], and the bottom image illustrates the results from the current numerical model.
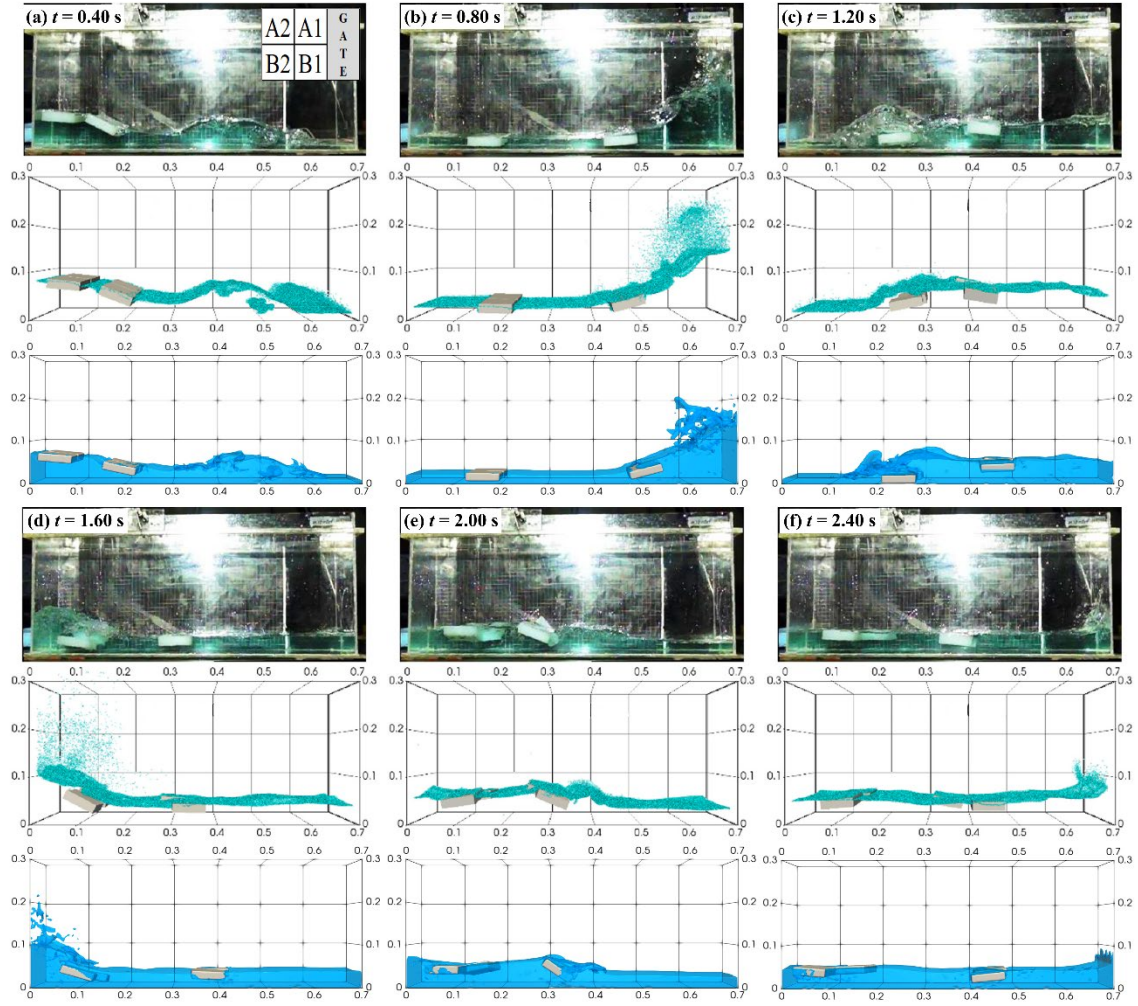
Figure S2: Snapshots of the TC4-1.0 at time intervals of (**a**) t=0.4 s, (**b**) t=0.8 s, (**c**) t=1.2 s, (**d**) t=1.6 s, (**e**) t=2.0 s, and (**f**) t=2.4 s. Each subfigure comprises three images: the top is the laboratory TC result, the middle is TC4-N by Amaro et al. [31], and the bottom image illustrates the results from the current numerical model.
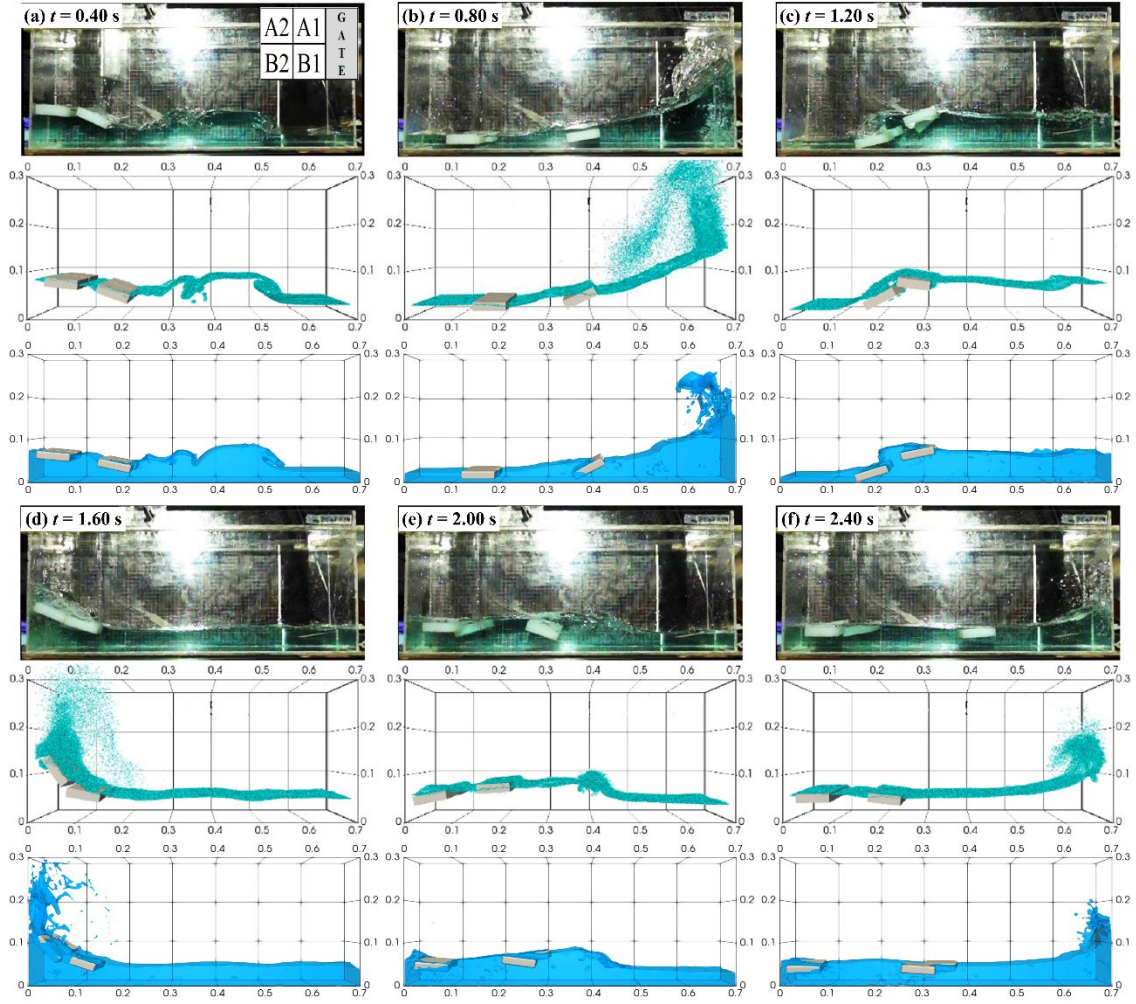
Figure S3: Snapshots of the TC4-2.5 at time intervals of (**a**) t=0.4 s, (**b**) t=0.8 s, (**c**) t=1.2 s, (**d**) t=1.6 s, (**e**) t=2.0 s, and (**f**) t=2.4 s. Each subfigure comprises three images: the top is the laboratory TC result, the middle is TC4-N by Amaro et al. [31], and the bottom image illustrates the results from the current numerical model.
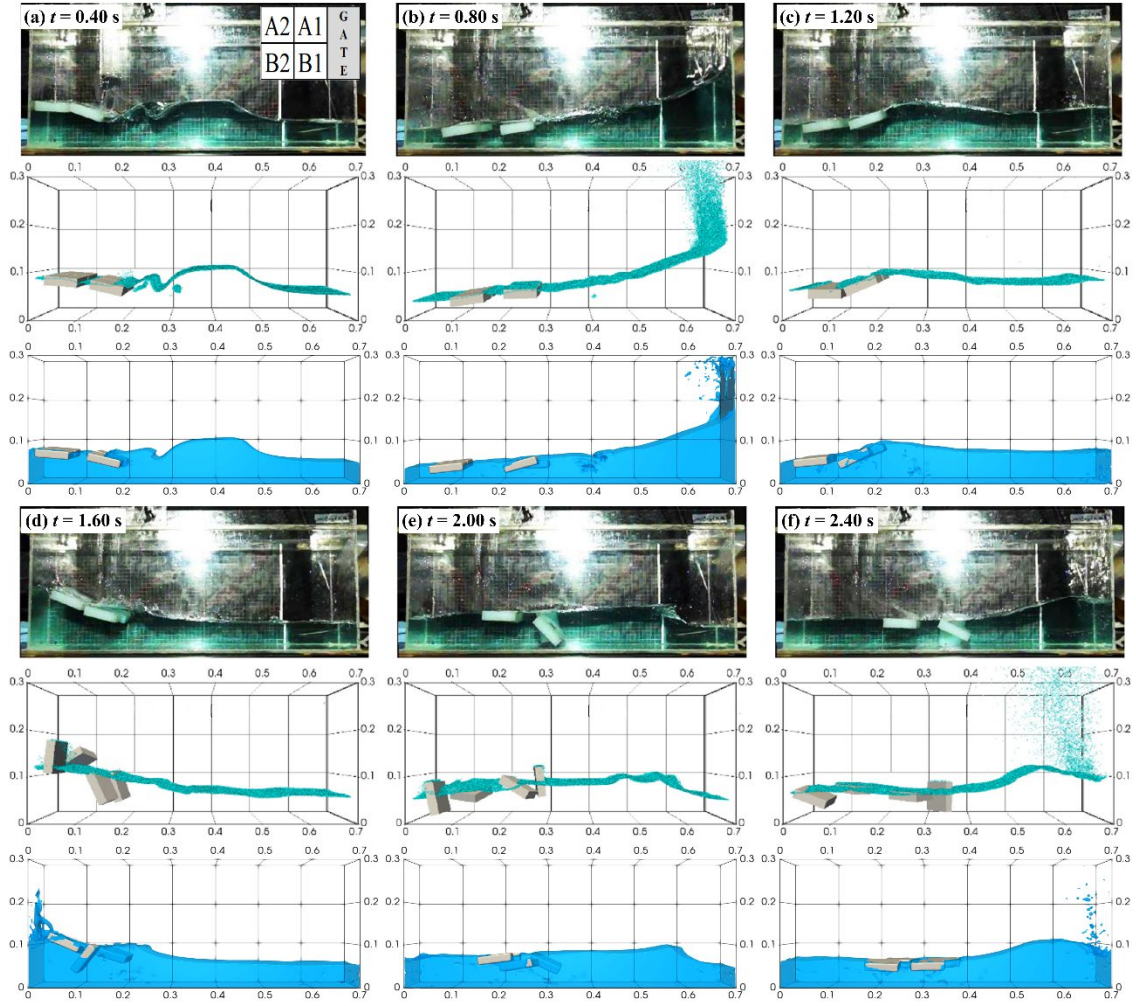
Figure S4: Snapshots of the TC4-5.0 at time intervals of (**a**) t=0.4 s, (**b**) t=0.8 s, (**c**) t=1.2 s, (**d**) t=1.6 s, (**e**) t=2.0 s, and (**f**) t=2.4 s. Each subfigure comprises three images: the top is the laboratory TC result, the middle is TC4-N by Amaro et al. [31], and the bottom image illustrates the results from the current numerical model.
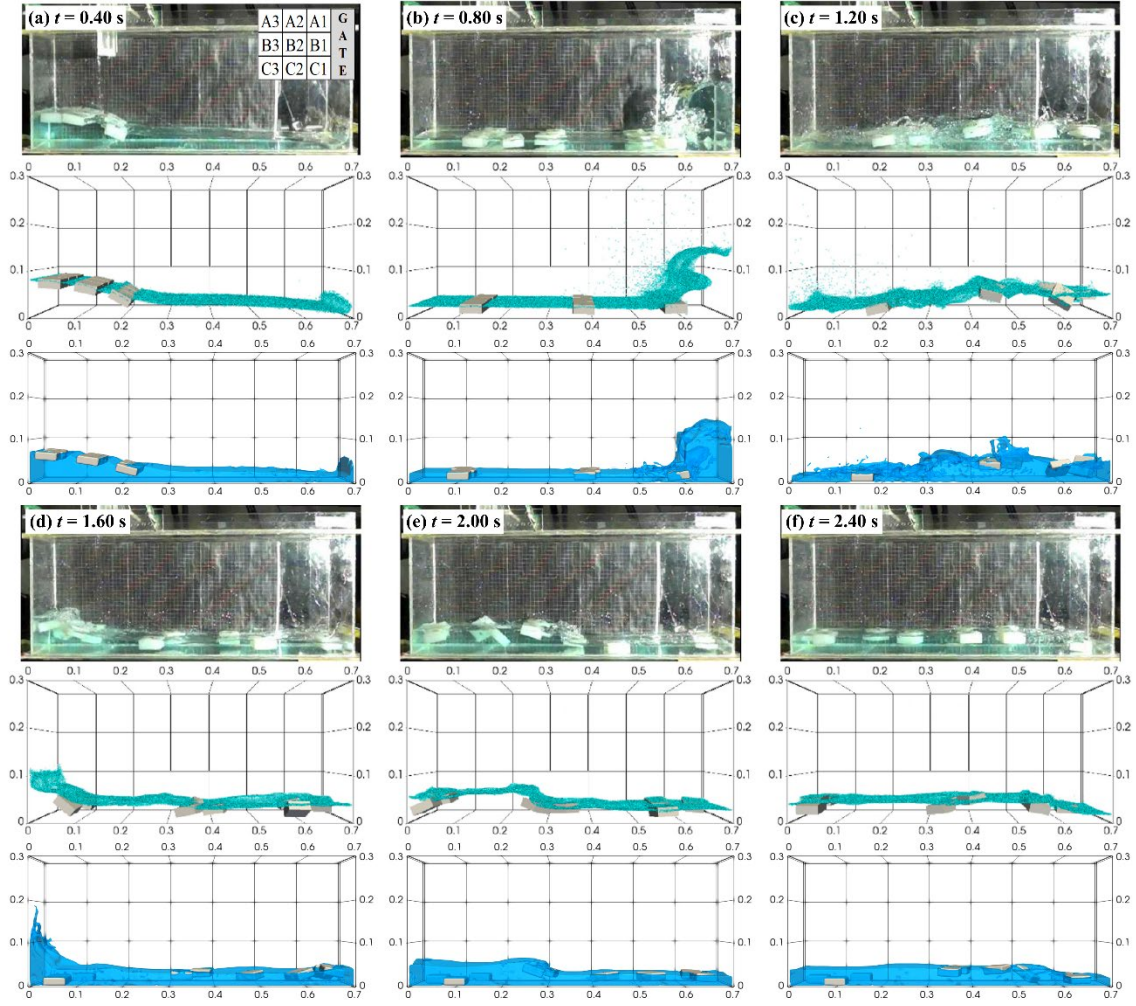
Figure S5: Snapshots of the TC9-0.0 at time intervals of (**a**) t=0.4 s, (**b**) t=0.8 s, (**c**) t=1.2 s, (**d**) t=1.6 s, (**e**) t=2.0 s, and (**f**) t=2.4 s. Each subfigure comprises three images: the top is the laboratory TC result, the middle is TC9-N by Amaro et al. [31], and the bottom image illustrates the results from the current numerical model.
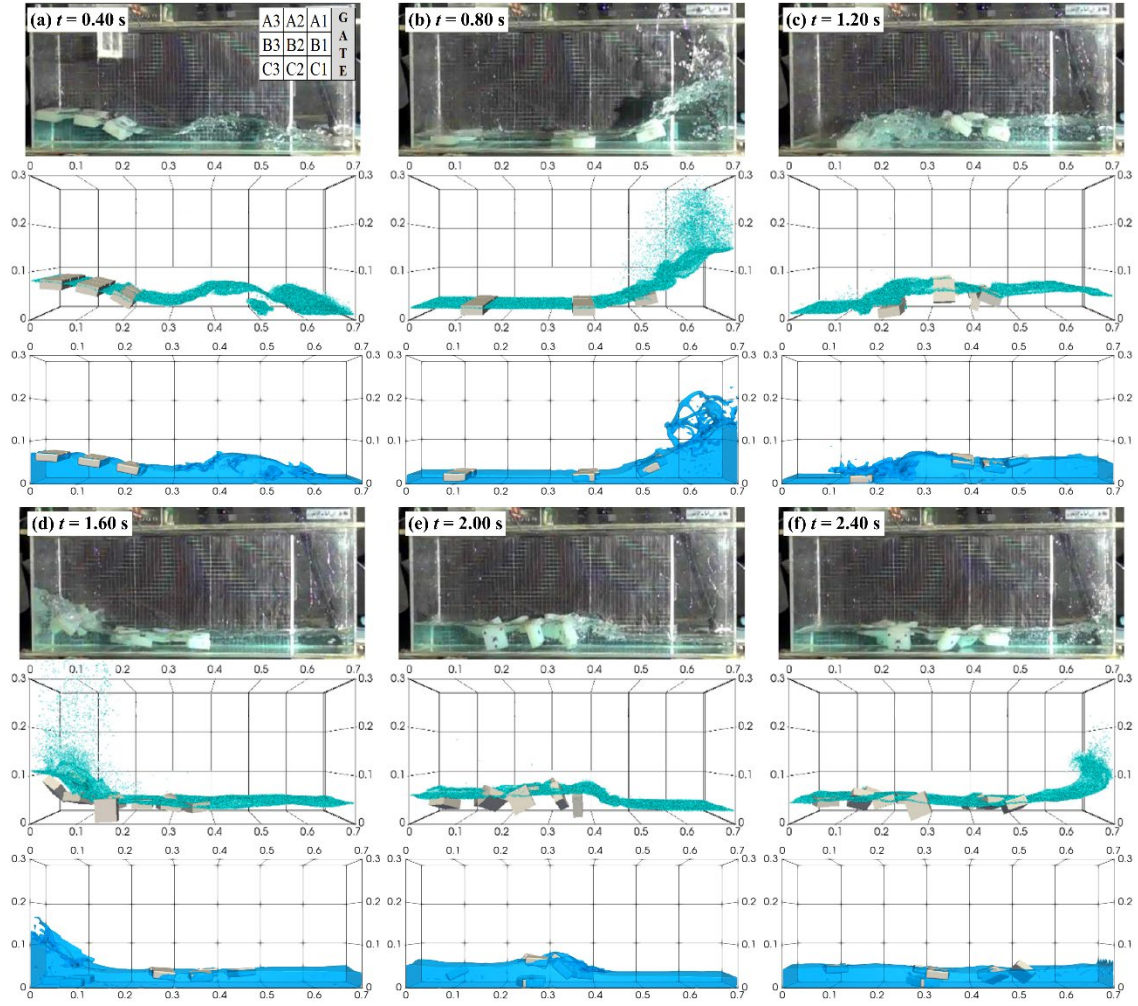
Figure S6: Snapshots of the TC9-1.0 at time intervals of (**a**) t=0.4 s, (**b**) t=0.8 s, (**c**) t=1.2 s, (**d**) t=1.6 s, (**e**) t=2.0 s, and (**f**) t=2.4 s. Each subfigure comprises three images: the top is the laboratory TC result, the middle is TC9-N by Amaro et al. [31], and the bottom image illustrates the results from the current numerical model.

Figure S7: Snapshots of the TC9-2.5 at time intervals of (**a**) t=0.4 s, (**b**) t=0.8 s, (**c**) t=1.2 s, (**d**) t=1.6 s, (**e**) t=2.0 s, and (**f**) t=2.4 s. Each subfigure comprises three images: the top is the laboratory TC result, the middle is TC9-N by Amaro et al. [31], and the bottom image illustrates the results from the current numerical model.
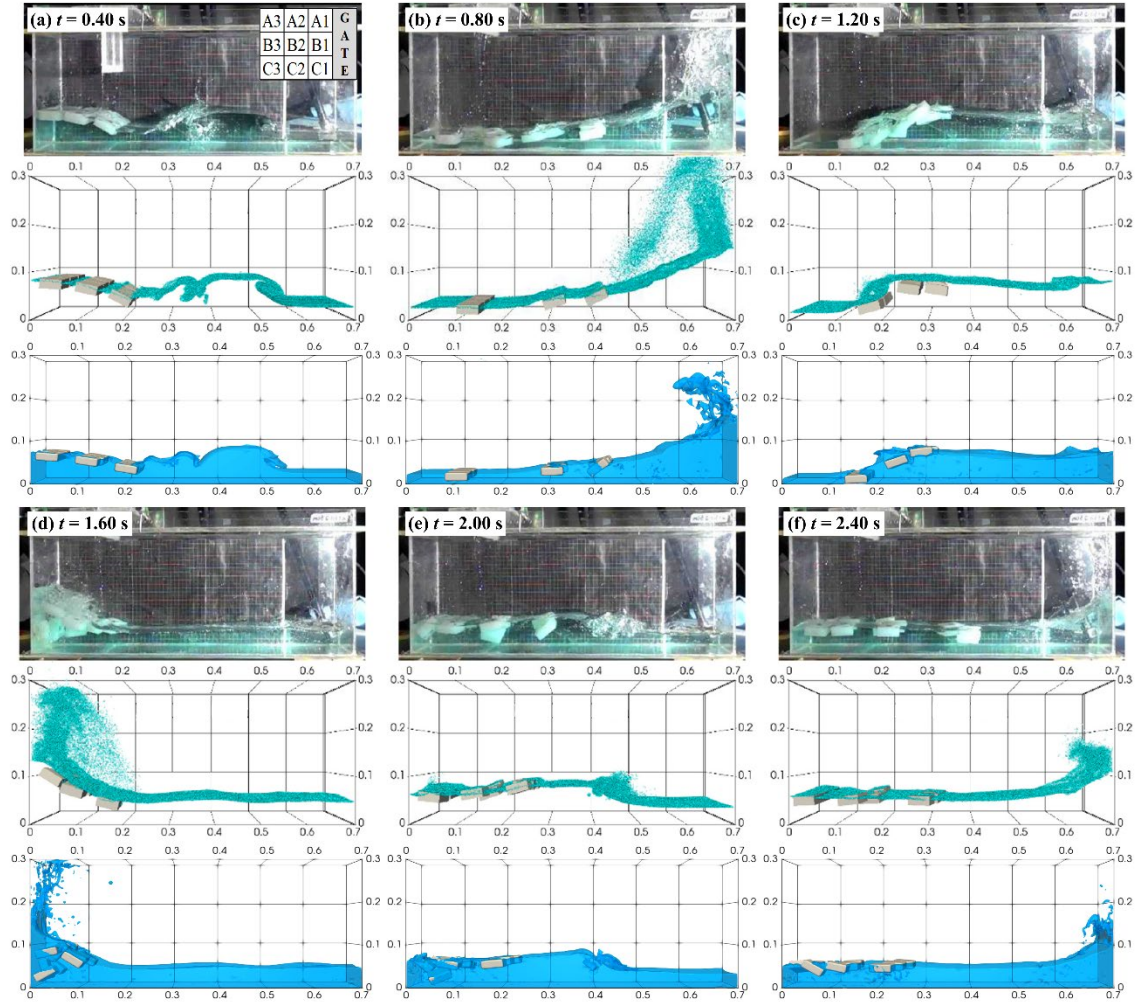
Figure S8: Snapshots of the TC9-5.0 at time intervals of (**a**) t=0.4 s, (**b**) t=0.8 s, (**c**) t=1.2 s, (**d**) t=1.6 s, (**e**) t=2.0 s, and (**f**) t=2.4 s. Each subfigure comprises three images: the top is the laboratory TC result, the middle is TC9-N by Amaro et al. [31], and the bottom image illustrates the results from the current numerical model.
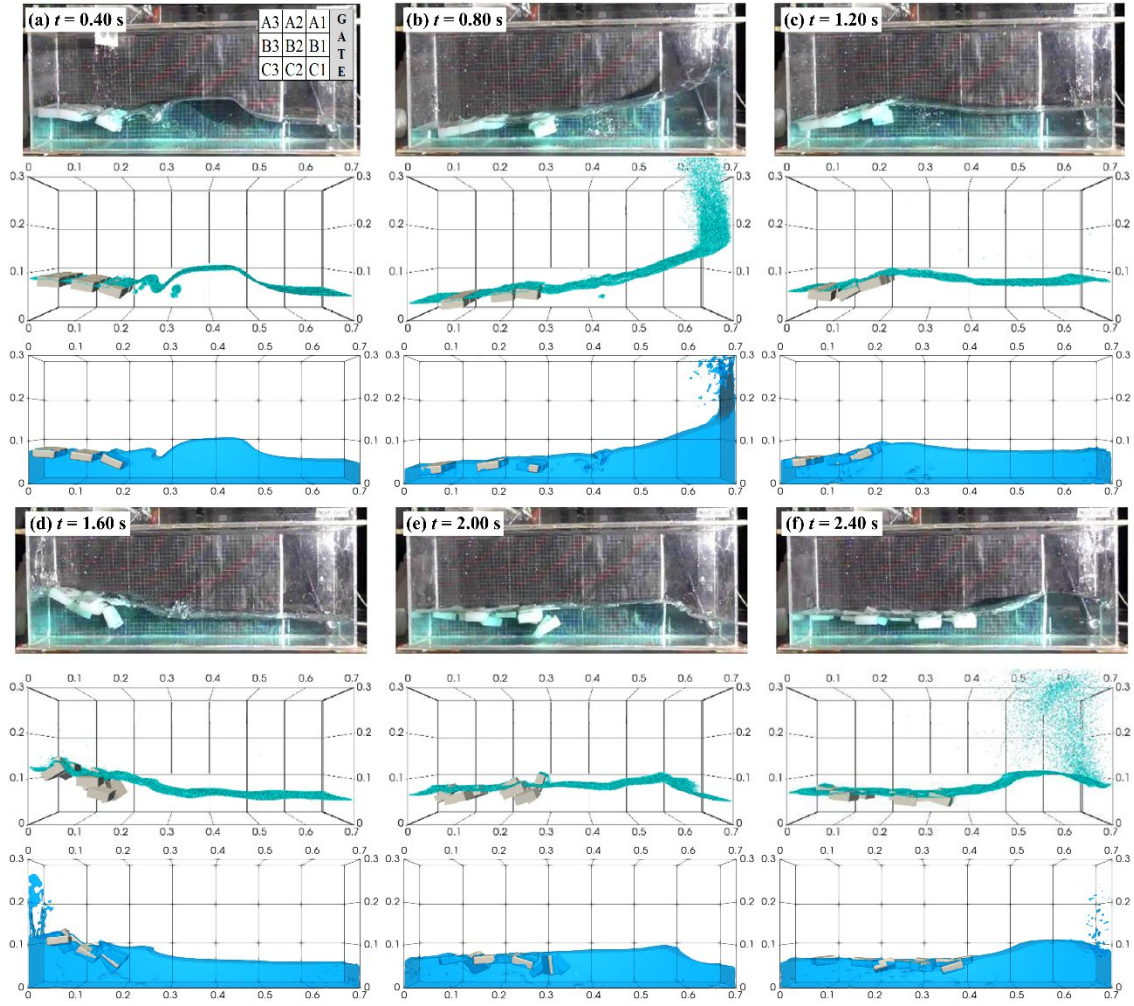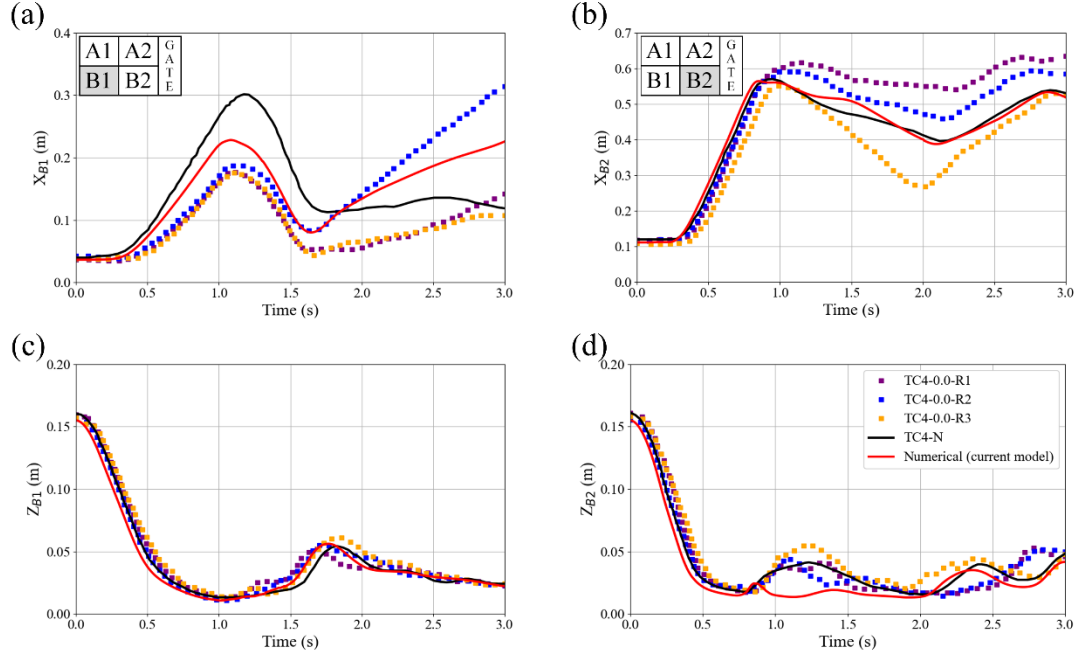
Figure S9: Comparison of the trajectory of the blocks from the laboratory experiment TC4-0.0 (different lines refer to the results of the different repetitions of the experiments TC4-0.0-R1, TC4-0.0-R2, and TC4-0.0-R3) with TC4-N from Amaro et al. [31] and the current numerical model for the x-direction of (**a**) Block B1 and (**b**) Block B2 and along the z-direction for (**c**) Block B1 and (**d**) Block B2.
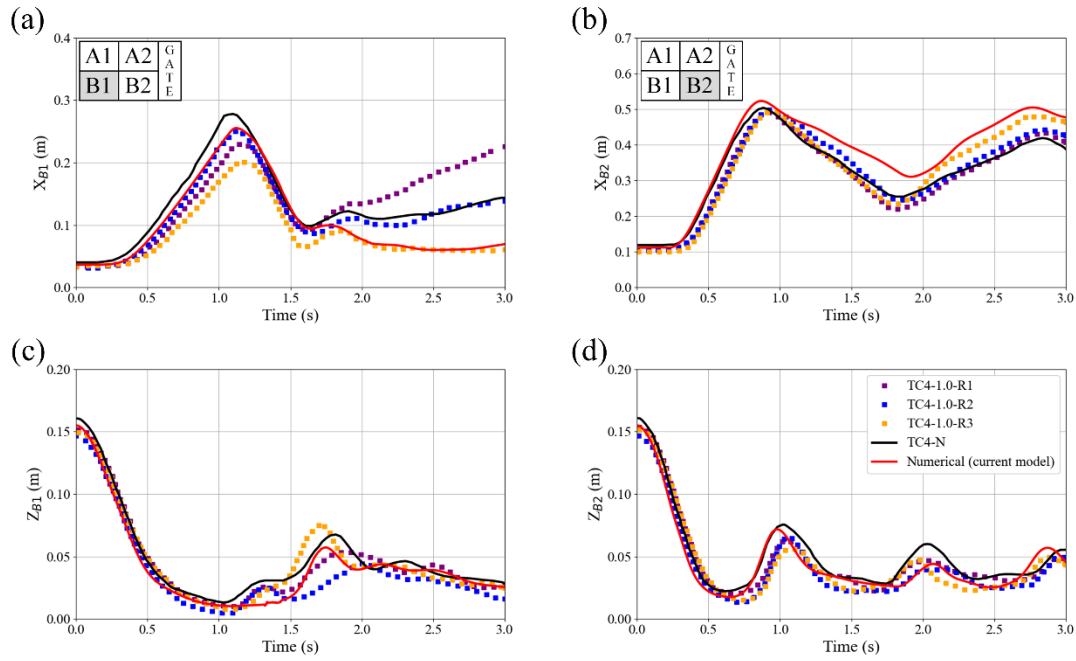

Figure S10: Comparison of the trajectory of the blocks from the laboratory experiment TC4-1.0 (different lines refer to the results of the different repetitions of the experiments TC4-1.0-R1, TC4-

1.0-R2, and TC4-1.0-R3) with TC4-N from Amaro et al. [31] and the current numerical model for the x-direction of (**a**) Block B1 and (**b**) Block B2 and along the z-direction for (**c**) Block B1 and (**d**) Block B2.
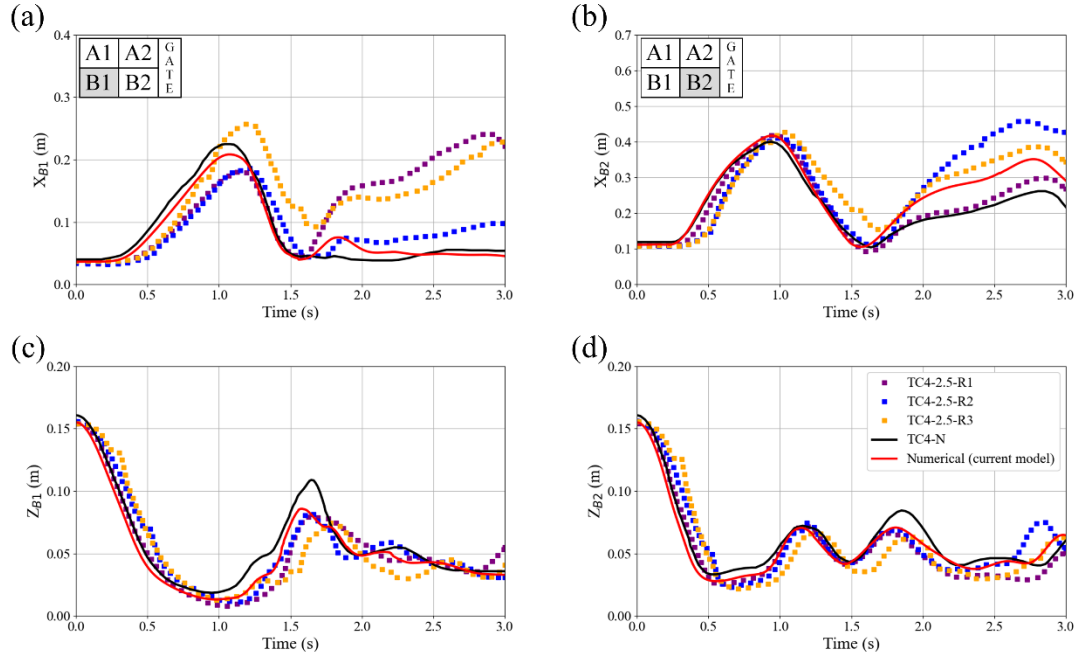

Figure S11: Comparison of the trajectory of the blocks from the laboratory experiment TC4-2.5 (different lines refer to the results of the different repetitions of the experiments TC4-2.5-R1, TC4-2.5-R2, and TC4-2.5-R3) with TC4-N from Amaro et al. [31] and the current numerical model for the x-direction of (**a**) Block B1 and (**b**) Block B2 and along the z-direction for (**c**) Block B1 and (**d**) Block B2.
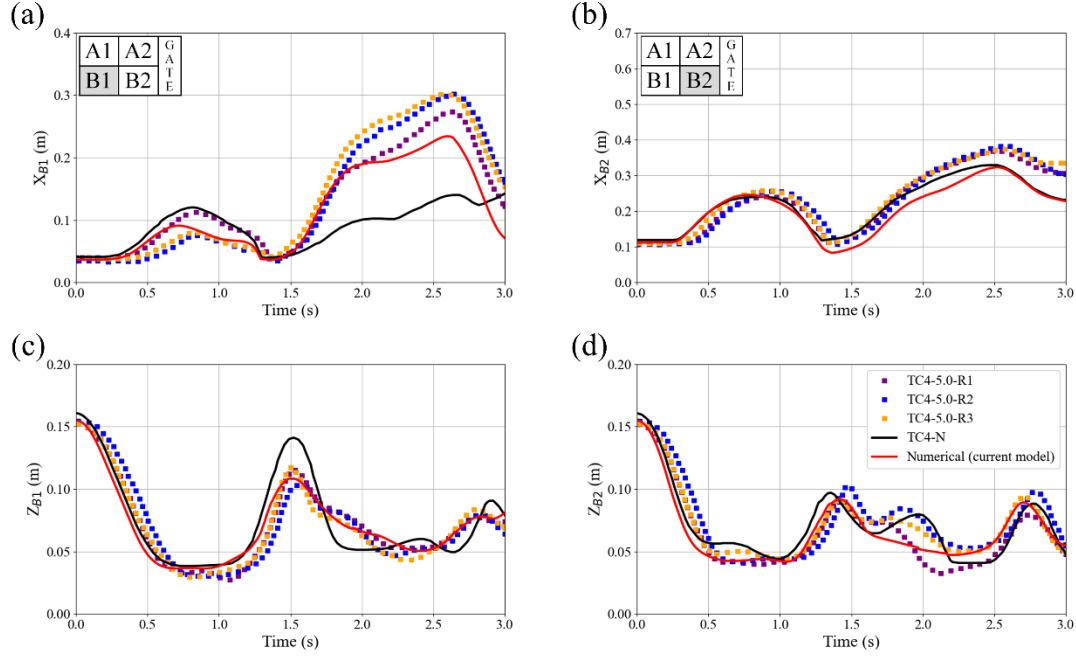
Figure S12: Comparison of the trajectory of the blocks from the laboratory experiment TC4-5.0 (different lines refer to the results of the different repetitions of the experiments TC4-5.0-R1, TC4-5.0-R2, and TC4-5.0-R3) with TC4-N from Amaro et al. [31] and the current numerical model for the x-direction of (**a**) Block B1 and (**b**) Block B2 and along the z-direction for (**c**) Block B1 and (**d**) Block B2.
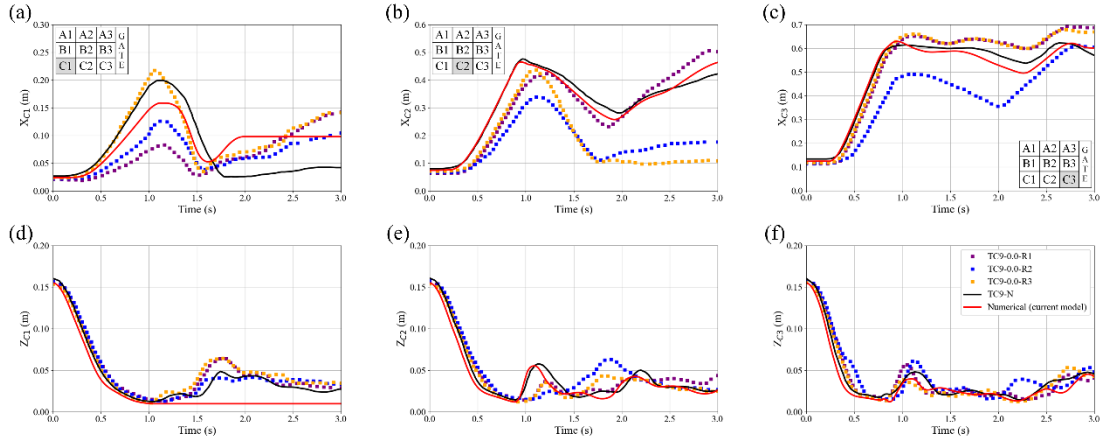

Figure S13: Comparison of the trajectory of the blocks from the laboratory experiment TC9-0.0 (different lines refer to the results of the different repetitions of the experiments TC9-0.0-R1, TC9-0.0-R2, and TC9-0.0-R3) with TC9-N from Amaro et al. [31] and the current numerical model for the x-direction of (**a**) Block C1, (**b**) Block C2, and (**c**) Block C3 and along the z-direction for (**d**) Block C1, (**e**) Block C2, and (**f**) Block C3.
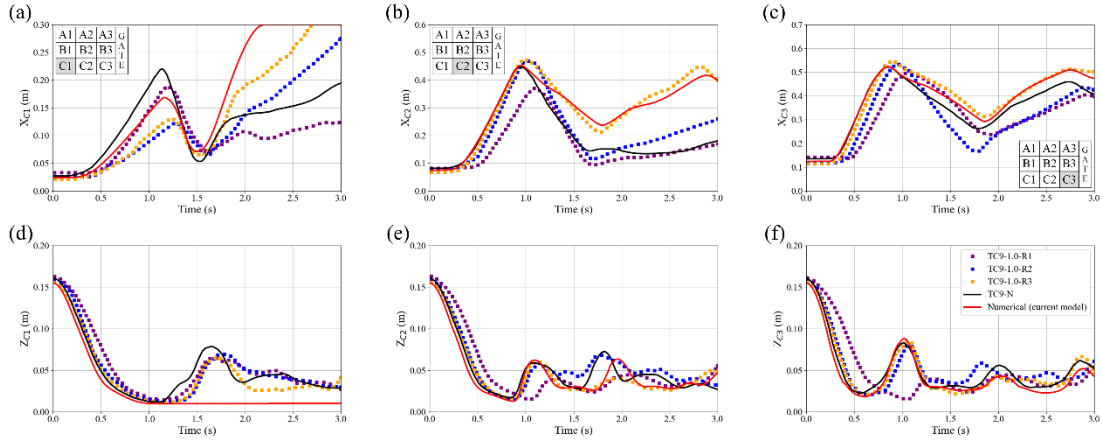
Figure S14: Comparison of the trajectory of the blocks from the laboratory experiment TC9-1.0 (different lines refer to the results of the different repetitions of the experiments TC9-1.0-R1, TC9-1.0-R2, and TC9-1.0-R3) with TC9-N from Amaro et al. [31] and the current numerical model for the x-direction of (**a**) Block C1, (**b**) Block C2, and (**c**) Block C3 and along the z-direction for (**d**) Block C1, (**e**) Block C2, and (**f**) Block C3.
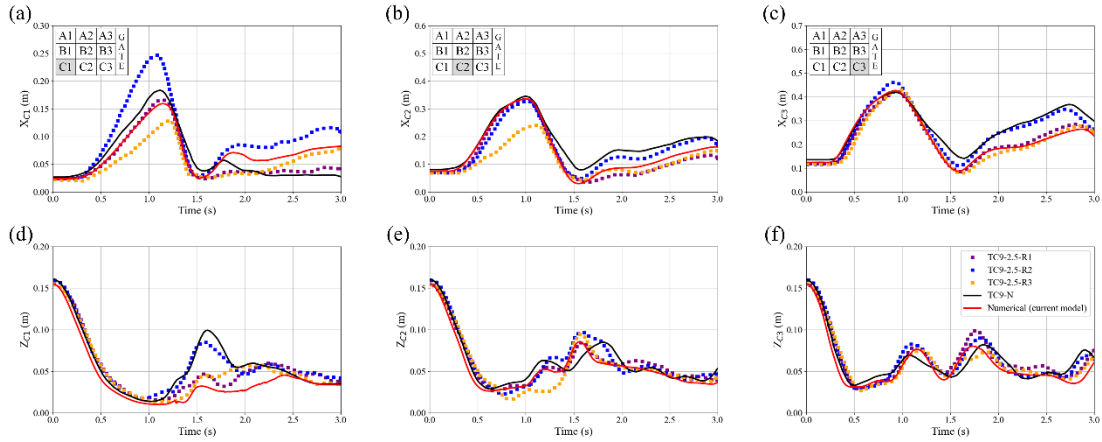

Figure S15: Comparison of the trajectory of the blocks from the laboratory experiment TC9-2.5 (different lines refer to the results of the different repetitions of the experiments TC9-2.5-R1, TC9-2.5-R2, and TC9-2.5-R3) with TC9-N from Amaro et al. [31] and the current numerical model for the x-direction of (**a**) Block C1, (**b**) Block C2, and (**c**) Block C3 and along the z-direction for (**d**) Block C1, (**e**) Block C2, and (**f**) Block C3.
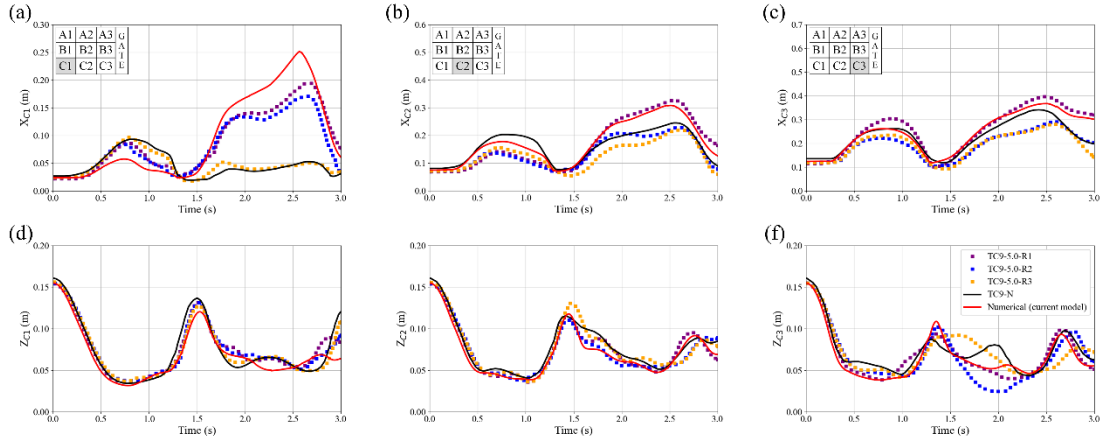
Figure S16: Comparison of the trajectory of the blocks from the laboratory experiment TC9-5.0 (different lines refer to the results of the different repetitions of the experiments TC9-5.0-R1, TC9-5.0-R2, and TC9-5.0-R3) with TC9-N from Amaro et al. [31] and the current numerical model for the x-direction of (**a**) Block C1, (**b**) Block C2, and (**c**) Block C3 and along the z-direction for (**d**) Block C1, (**e**) Block C2, and (**f**) Block C3.