Investigative research concerning hydraulic analysis methods of storage pipes using computational fluid dynamics (Yokohama City)		
Year of Research	2013・2014	Implementation of anti-inundation measures

(Purpose)

In Yokohama City, there was a heavy rain with the hourly rainfall intensity of 55 mm/hr from April 7 to 8, 2013. This caused the levitation of manholes of storage pipes and surrounding pavement, resulting in the scattering of crushed stones in the vicinity, damaging the vehicles.

Objective of the present study is to reproduce the conditions at the time of occurrence of accident using computational fluid dynamics (CFD), understand the root causes, formulate countermeasures, and verify their effect.

(Results)

(1) Situation of damage

Heavy rain levitated the manhole inclined walls, and damaged and deformed the peripheral pavements of sidewalks. We could not confirm overflow stream around the places where levitation had occurred. Therefore, it can be presumed that air hammer phenomenon due to compression of air inside the pipes would have occurred.

(2) Uneven distribution of rainfall

We analyzed the rainfall situation at the time of occurrence of levitation of manholes using X Band MP Radar information. As a result, we could confirm uneven distribution of rainfall with the rainfall region moving from downstream to upstream (places where levitation of manholes had occurred).

(3) Evaluation of flow regime based on run-off analysis model

From the analytical results of the overall basin using the run-off analysis model, we could confirm that backward flow was generated from the downstream side of the storage tube at the estimated time of occurrence of levitation of manhole. Because of that, downstream side sewer pipe of the manhole where accident occurred became full, and there was no place for air inside the manhole to escape. As a result, in the manhole where accident had occurred, inflow from the upstream side and backward flow from the downstream side got together from both the sides, causing sudden compression of air.

(4) Analyzing the effect of air compression

We simply calculated the effect of air compression inside the levitated manhole using one-dimensional computational analysis. Moreover, we also verified the effect of temporary outlet (provisional measure) installed after taking the measures. It came to light that increasing the air holes decreased the discharging wind speed, which reduced the effect of air compression in the manhole.

(5) Modeling of computational fluid dynamics (CFD)

In this facility, there were several sewer pipe joints, and it is possible that there was effect of complex hydraulic phenomena in terms of mixing (multiphase flow) of water and air such as compression of air pocket inside the sewer pipes and air entrainment in the parts where air drop had occurred.

In order to understand this complex situation, we decided to conduct CFD analysis used as three-dimensional fluid analysis, and we conducting modeling and trial calculation for pipe lines around the area where accident had occurred (refer to **Figure 1**).

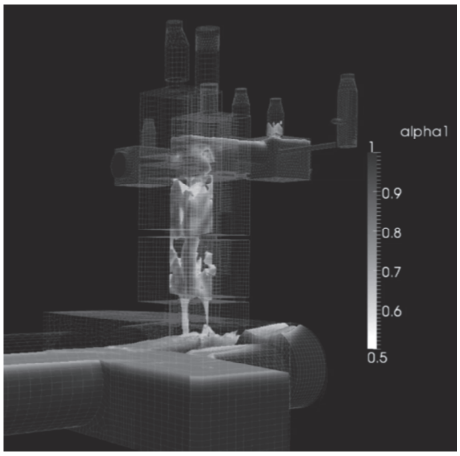

Figure 1 CFD analysis

(Future prospects)

Going forward, in addition to conducting quantitative analysis of root cause for accidents such as calculation of pressure inside the manhole by doing CFD analysis of the model that we have developed, we plan to verify the effect of exhaust vents used as provisional measure. Moreover, we would also like to check the quantity of measures required for preventing the occurrence of accidents.

This study presents the analytical approach for complex fluid (gas-liquid mixing fluid) inside the sewerage pipes, which would help in highly accurate and safe design of pipes for heavy rainfall, which has become frequent in the recent years.

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