# Approaches to Practical Sewer Pipe Inspection Technology Using Drones, Based on Public-Private-Academic Partnership


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## INTRODUCTION

City of Yokohama, with an area of 42,531ha and a total population of approximately 3.74 million, has enormous amount of assets compared to other sewerage facilities — 99.9% coverage of sewerage supply system, approximate 11,900km in total pipe length of the sewerage pipeline facility, about 530,000 pieces of manholes, about 1,400,000 pieces of inlets and service connections, and investment of about 2.7 trillion yen already made (approximately 70% of total amount of investment). Currently, approximate 800km (7%) of total pipe length has ended its 50 years of standard service life. It'll be expected to get deteriorated rapidly, like approximate 2,800km (24%) after one decade and approximate 7,900km (67%) after two decades.

This time, we will report about engagement in collaborative investigation into the medium to large diameter pipe that makes up approximate 1,900km of total pipe length, toward the practical use of a new inspection technique utilizing unmanned aerial vehicles (hereinafter, drones) that are gradually utilized for infrastructure inspections, etc.

【Aims of this investigation】
・To ensure the workers' safety in pipelines that are difficult to investigate
(work in drastic swollen water by torrential rain, or in oxigenless/hydrogen sulfide generated environment)
・To reduce the cost for inspections (improve productivity)
(reduction in the inspection cost by improvement of running speed, etc. compared to conventional underwater visual inspections and self-propelled TV camera car, etc.)


【Keywords】Drone, Industry-academia-government, Sewerage inspection survey, Medium to large diameter pipe



Steep gradient


Oxygen deficiency / toxic gas environment


Attachment of grease

Picture 1 Example of pipelines that are difficult to investigate
Photo provider : Ministry of Land, Infrastructure, Transport and Tourism National Institute for Land and Infrastructure Management

## METHODS

【Flight control styles of drones】
・"Manual flight"; visual flight that you operate while directly watching a drone, or non-visual flight that you operate while watching a screen image at hand.
・"Automatic flight"; control a flight with a variety of sensors mounted on a drone.

【Problems in applying drones to pipe inspections】
・Non-GPS environment
・Darkness
・Sewage is flowing
・Narrow space
・Needs to carry inspection equipment from a manhole cover.
⇒Compared to the other infrastructure inspections conducted with drones, this application faces the hardest environment.

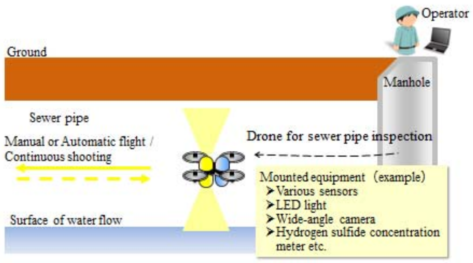


Figure 1 Diagram of inspection with a drone

## RESULTS

【Investigation results】

**・Applied caliber**
・Stable flights are confirmed in circular pipes from φ1800mm to φ3000mm.
*In φ1500mm of circular pipe, a flight is not stable due to reflecting wind made by a drone itself.

**・Inspection level (trouble confirmation accuracy)**
・Got similar images as pictures along the direct vision in the underwater visual inspections.
・Got a result that rank A and B were basically available to be judged.
*Didn't get images reaching detail inspection level

**・Flight length**
・φ3000mm : from 45m to 500m
*Judgment on the basis of operators' abilities and stable condition of flights
・Other flight length of each caliber (see Table 4).

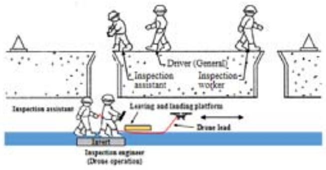


Figure 3 Pattern diagram of inspection work by drone

Table 4 Summary of flight experiment results

| Classification | Manual flight | | | | | | | | Automatic flight |
|---|---|---|---|---|---|---|---|---|---|
| Caliber of test target pipe | Φ1500 | | Φ1800 | Φ2000 | Φ2350 | □2700 × 2700 | Φ3000 | | □2700 × 2700 |
| Pipe classification | Combined sewer | Rainwater pipe | Rainwater pipe | Rainwater pipe | Rainwater pipe | (Former combined sewer) | Combined sewer | Rainwater pipe | (Former combined sewer) |
| Planar linear | Strait line | Strait line | Strait line / Curve mixed | Curve | Curve | Strait line | Strait line | Curve | Strait line |
| Presence of water flow (water depth) | Yes (25 cm) | No (Water stagnant in some sections) | No | No | No | No | Yes (30 cm) | No | No |
| Used aircraft *2 Flight record One way extension One way / round trip | P: 12 m (Round trip) | M.P: 20 m (Round trip) | M.P: Strait line part 66 m (Round trip) Curve part 32 m (One way) | P: 540 m (One way) | M.P.S: 30 m (Round trip) F: 175 m (One way) | M.P.F: 30 m (Round trip) | P.S: 45 m (Round trip) | P: 500 m (One way) | --- (Hovering only) |

*2 Used aircraft M: Mavic Pro, P: Phantom 4 Pro, S: Splash Drone 3, F: Flyability

## DISCUSSION

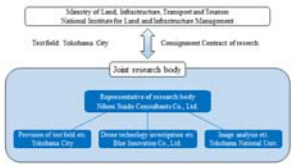


Figure 2 Division of roles of investigation community

Table 1 Investigation aims

| | Target level | Note |
|---|---|---|
| Manual flight | Screening inspection | ➢ Screening inspection cost is about 1/3 ~ 1/5 of the conventional technology |
| | Detailed inspection | ➢ Detailed inspection cost is less than the conventional technology |
| Automatic flight | Realization of stable flight | ➢ Practical application of new sensor-equipped aircraft |

Target pipe category: Sanitary sewer, combined sewer
Target pipe caliber: Φ 1500 mm or more
Extension per span: 150 m

Table 2 Criteria

| Judgment item | Rank A | Rank B | Rank C |
|---|---|---|---|
| 1) Corrosion of pipe | Rebar exposed condition | Aggregate exposed state | Surface is rough |
| 2) Sagging in the vertical direction | 1/4 or more of inner caliber | 1/8 or more of inner caliber | Less than 1/8 of inner caliber |
| 3) Pipe breakage | Missing | With axial cracks width 2 mm or more | With axial cracks width less than 2 mm |
| 4) Pipe crack | With circumferential crack width 5 mm or more | With circumferential crack width 2 mm or more | With circumferential crack width less than 2 mm |
| 5) Joint displacement of pipe | Break away | 70 mm or more | Less than 70 mm |
| 6) Intrusion water | Blowing out | Flowing | Oozing |
| 7) Overhang of mounting pipe | 1/2 or more of main pipe inner caliber | 1/10 or more of main pipe inner caliber | Less than 1/10 of main pipe inner caliber |
| 8) Attachment of grease | 1/2 or more of inner caliber blocked | Less than 1/2 of inner caliber blocked | --- |
| 9) Tree invasion | 1/2 or more of inner caliber blocked | Less than 1/2 of inner caliber blocked | --- |
| 10) Mortar adhesion | 30% or more of inner caliber | 10% or more of inner caliber | Less than10% of inner caliber |

【Description of field experiments】
"Manual flight"
・Aimed at reducing costs, LED lights, etc. are customized based on commercial aircrafts.
"Automatic flight"
・Aimed at flying automatically while estimating locations, a variety of sensors, like lasers, and a spherical guide are mounted by our original development.

Table 3 Overview of the aircrafts used in this study

| Classification | Manual aircraft body | | | | Automatic Aircraft body |
|---|---|---|---|---|---|
| Aircraft name | Commercial aircraft 1 Mavic Pro | Commercial aircraft 2 Phantom 4 Pro | Commercial aircraft 3 Splash Drone 3 | Commercial aircraft 4 Flyability | To be determined |
| Aircraft photograph |  |  |  |  |  |
| Carry into manhole (Passability through manhole lid of Φ 600) | ○ | ○ | △ carry-able into manhole if removing propeller | ○ | ○ |
| Aircraft weight | About 1.1 kg | About 1.4 kg | About 2.4 kg | About 0.7 kg | About 1.3 kg |
| Payload | About 0.3 kg *1 | About 1 kg *1 | About 1 kg | --- | About 0.2 kg |
| Light | Added a commercially available LED | Added a commercially available LED | Added a commercially available LED | Standard LED only | (Not installed) |
| Waterproof | × | × | ○ | × | × |
| Camera | Standard camera only | Upper: Commercial camera Bottom: Standard camera | Upper: Commercial camera Bottom: Standard camera | Standard camera only | (Not installed) |

*1 Figures independently investigated by the research body (not the manufacturer's release value)

## CONCLUSIONS

【Manual flight】
・Its utility as a screening inspection has been proved
・It costs about 2/3 of conventional cost

【Automatic flight】
・A stable automatic flight hasn't been achieved

【Tasks】
・Apply aircrafts having "waterproof property"
・Achieve "cost reduction"

Picture 2 Experiment scenes


References:
(1) Road map on formulating plans to extend the service life of sewerage on the basis of physical asset management method (Proposal) Sep. 2013 Sewerage and Wastewater Management Department, Water and Disaster Management Bureau, MLIT
(2) Mikio Urabe and others from Nihon Suido Consultants Co., Ltd. "Engagement in practical use of the pipe corrosion investigation technique, utilizing unmanned aerial vehicles" The 55th Sewerage Investigation Workshop, collection of lectures