FIELD INVESTIGATION OF LONG-TERM MOORING CHAIN SYSTEM DURABILITY OF THE GPS TSUNAMI-WAVE METER

Yukihiro TERADA[1], Toshihiko NAGAI[2], Teruyuki KATO[3], Yasuhiro MATSUSHITA[4], Koji KAWAGUCHI[5]

(1)Doctor of Engineering, Professor, Kochi National College of Technology, Japan, terada@ce.kochi-ct.ac.jp

(2) Doctor of Engineering, Executive, ECOH Corp., Japan, t-nagai@ecoh.co.jp

(3) Doctor of Science, Professor, Earthquake Research Institute, the University of Tokyo, Japan, teru@eri.u-tokyo.ac.jp

(4) General Manager of Marine Civil Engineering Project Execution Department, Hitachizosen Corp., Japan, matsushita_ya@hitachizosen.co.jp

(5) Doctor of Engineering, Head of Marine Information Group, Marine Information and Tsunami Research Division, Port and Airport Research Institute, Japan, kawaguchi@pari.go.jp

① INTRODUCTION

This paper aims for providing basic information of the mooring design of the GPS mounted Tsunami-Wave meter buoy (Nagai, et.al, 2006 and 2007), which successfully observed exact offshore tsunami profile of the 2011 off the Pacific coast of Tohoku Earthquake.

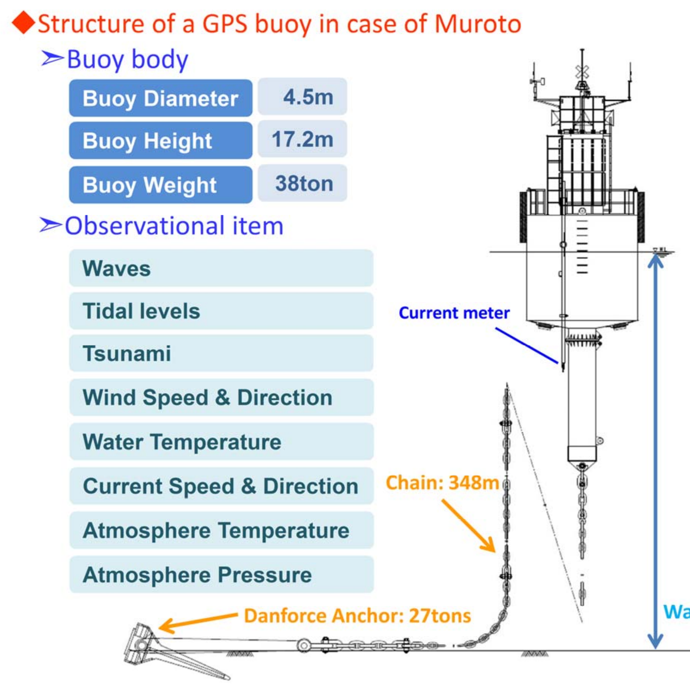
In this poster, authors introduce observation data of proto-type GPS buoy's mooring chain at 3 years and 7 months after the installation in the severe sea condition, in order to provide information for future safer and more economical design of the mooring system.

② GPS BUOY MOORING SYSTEM

Mooring system of the GPS buoy needs to be designed to follow the wave actions as much as possible, in order to obtain more exact ocean wave and tsunami data.

This is why the GPS buoy mooring system adopts the unique single anchor catenary chain mooring system, which is supposed to follow up water surface elevation well for long time without interrupting wave observation for less mooring line replacement work.

Nevertheless, up to present, we have not enough field data of the long-term durability of the mooring chain system against damage and frictional wear due to the continuous buoy motion.



③ CONDITION OF THE PROTO-TYPE GPS BUOY TEST

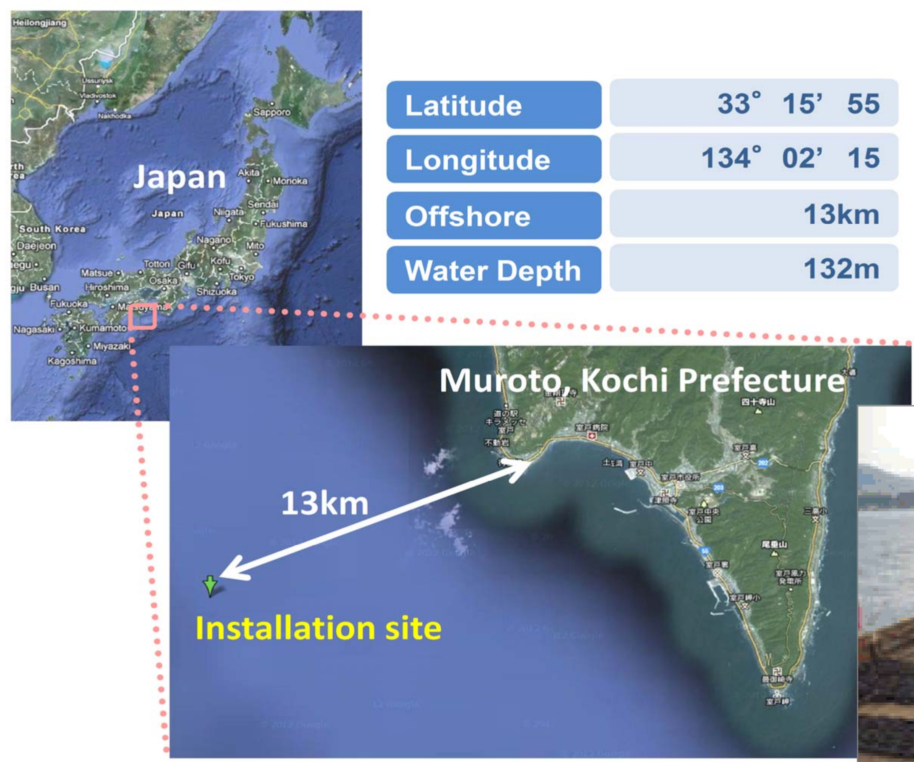
The proto-type testing GPS buoy was installed at the water depth of 128m and 13km off the Muroto-Misaki on April 21, 2008, and was pulled up on November 25, 2011.

Authors carefully observed and measured the pulled up chain system comparing to its initial conditions when it was installed.

The design for the significant wave height of the buoy was set as 14.94m based on the 50 years expected wave simulation.

Actual observed maximum significant wave height during the test term was 8.44m during the typhoon No.1106 attack. In addition, two major tsunamis attacked the buoy system during the test term. One is the 2010 Chile earthquake tsunami on March 28, 2010 (JST) whose tsunami wave height was 20cm (Terada, et.al, 2011), and the other is the 2011 off the Pacific coast of Tohoku Earthquake tsunami on March 11 (JST) whose tsunami wave height was 40cm (Terada, et.al, 2013).

The situation at the time of the setting (2008/4/21)



Pulled up GPS Buoy after Long-term Observation (2011/11/25)

④ MOORING CHAIN DURABILITY DATA

The detailed information of the mooring chain system is demonstrated, describing each chain thickness in millimeter. Thickness of the mooring chain of 348m in total length differs depending on the location.

The thickness of the chain No.1 was set as 139mm, considering that annual frictional ware rate is 10mm/year during 10 years design life term.

Thickness is constant (68mm) between the chain No.236 and No.396 (119.6m below the mean sea level), for these chains do not touch the seabed even at the expected maximum vertical motion of the buoy in the designed severe wave condition.

Thickness of chains No.400 to No.561 (169.8m downward from the mean sea level) were designed as 76mm, for those chains are expected to suffer larger frictional ware due to repeated landing and dis-landing by the buoy motion. The designed frictional wear rate of these chains was 3mm/year during 10 years design life term.

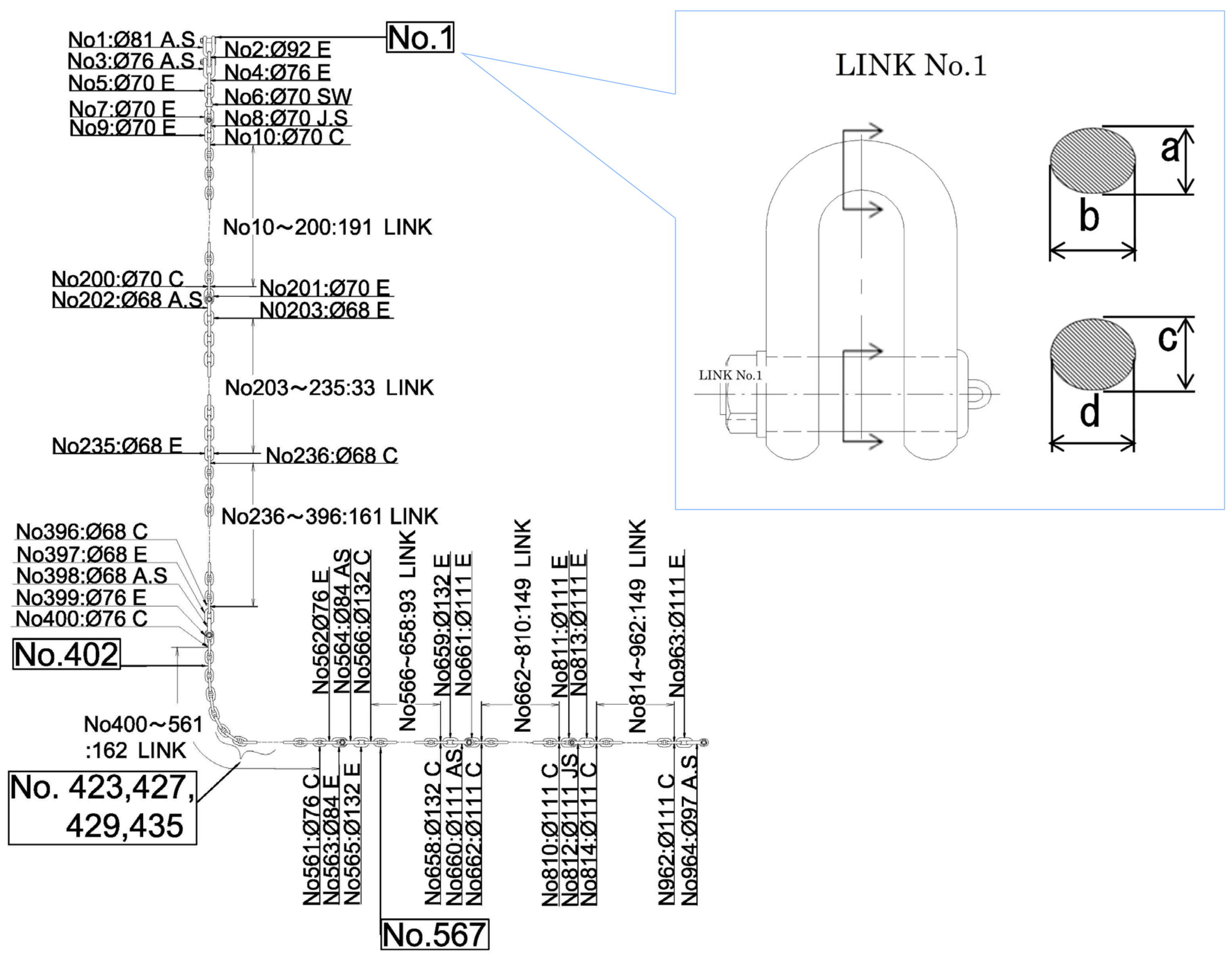
Thickness is constant (132mm) between the chain No.566 and No.658, and also constant (111mm) between the chain No.662 and No.962 (except No.811-813 connector chains), to suppress the chain rise from seabed by increasing its weight.

Photo shows situation of a buoy bottom end shackle and No. 1 chain when pulled up from the sea. Although large amount of the sea plants like shells can be seen on the shackle and chain, the mooring system seemed to keep good condition without losing its strength.

Definition of the measured thickness of the chain "a" and "b" is also demonstrated. Parameters "c" and "d" indicates thickness of the buoy bottom end shackle of the two different perpendicular axis.

The Table shows the result of the representative chains' measured thickness diameters just after the buoy and mooring chains were pulled up to the deck of the working vessel.

No	Specification	below the mean sea level (m)	Diameter : a		
			Design (mm)	Measure (mm)	Wear rate (mm/year)
No.1	φ81AS	9.2	139	133	1.71
No.402	φ76C	121.4	76	73	0.86
No.423	φ76C	127.8	76	72	1.14
No.427	φ76C	129.0	76	69	2.00
No.429	φ76C	129.6	76	70	1.71
No.435	φ76C	131.4	76	73	0.86
No.567	φ132C	172.5	132	130	0.57



⑤ CONCLUSIONS

Following findings may be important for the future GPS buoy design.

(1) Mooring chains stayed in good performance even after 3 years and 7 months of severe ocean field conditions, although they were covered by large amount of sea plants like shells and several studs disappeared from some of the chains located at frequently suffering from landing and dis-landing action by the buoy motion.

(2) The quantity of real frictional wear was considerably smaller than assumed one at all the part of the mooring system.

(3) Maximum real frictional wear was observed at chains located at frequently suffering from landing and dis-landing action by the buoy motion.

⑥ References

Nagai, T., Kato, T., Moritani, N., Izumi, H., Terada, Y. and Mitsui, M.(2006): Offshore Tsunami Monitoring Network Design using GPS Buoys and Coastal on-site Sensors, ASCE, Proc. of the 30th International Conference on Coastal Engineering (ICCE'06) vol.2, pp.1529-1540.

Nagai, T., Shimizu, K., Lee, J.H., Iwasaki, M., Fujita, T. and Kudaka, M.(2007): Development Of Muli-Purpose Offshore Observation System Using Gps Buoy, Proceedings of Coastal Structures 2007 International Conference, Vol.1, pp.669-680.

Terada, Y., Kato, T., Nagai, T., Koshimura, S., Miyake, T., Nishimura, H. and Kunihiro, S.(2011): Development of a tsunami monitoring system using a GPS Buoy, Proc. IGNSS 2011, International Global Navigation Satellite Systems Society, Paper No.14, 12p. (CD-Rom)

Terada, Y., Kato, T., Nagai, T., Kawaguchi, K., Koshimura, S. and Matsushita Y.(2013): An improvement of the GPS buoy system for detecting tsunami at far offshore, Book of Abstract, the International Association of Geodesy (IAG) Scientific Assembly, p.409.