UAV-based Smart Rock Localization for Determination of Bridge Scour Depth

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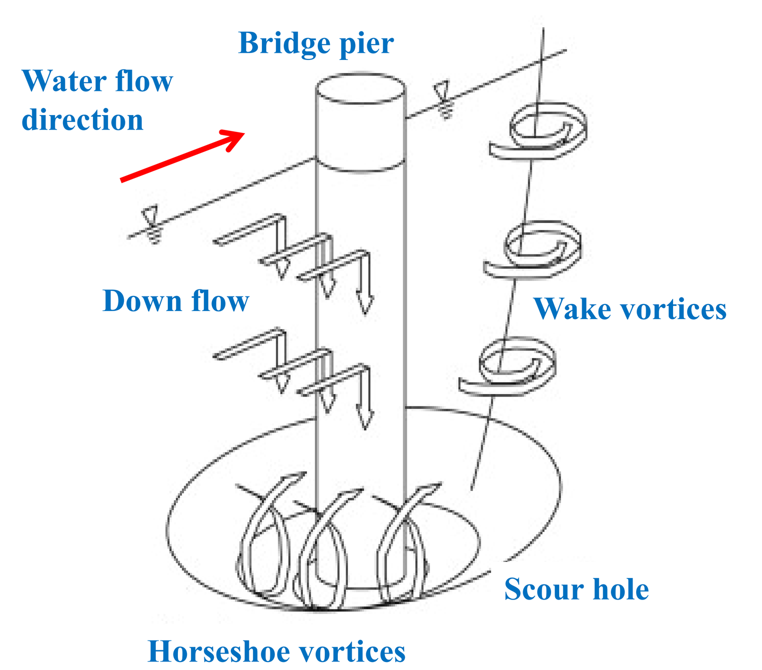
INTRODUCTION

Scour and other hydraulic induced failures accounted for 58% of over 1,500 bridge collapses in the U.S. In the world, bridge scour is also one of the biggest factors leading to bridge failure. Bridge scour is due to the erosion of soil surrounding a bridge foundation as a result of water current.

Monitoring with **fixed** or **portable** instrumentations is the most effective measure in mitigating scour hazards. However, **fixed** instrumentation with sensors installed prior to flood events cannot detect scour other than the area instrumented. Moreover, It is susceptible to the harsh environment during a flood event. **Portable** instrumentation is difficult to deploy during a severe flood event due to safety consideration and/or water conditions.

Typical bridge scour accident



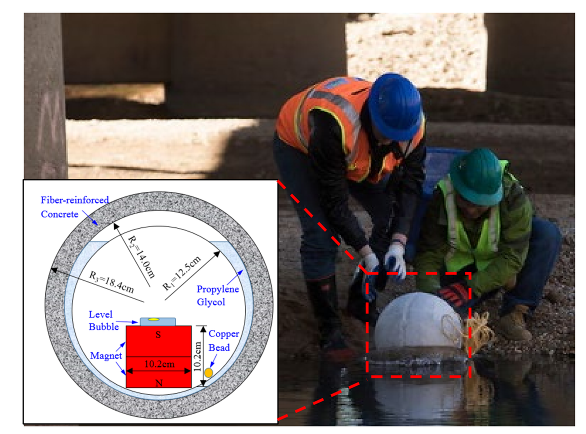
Scour mechanism around a bridge pier

METHODS

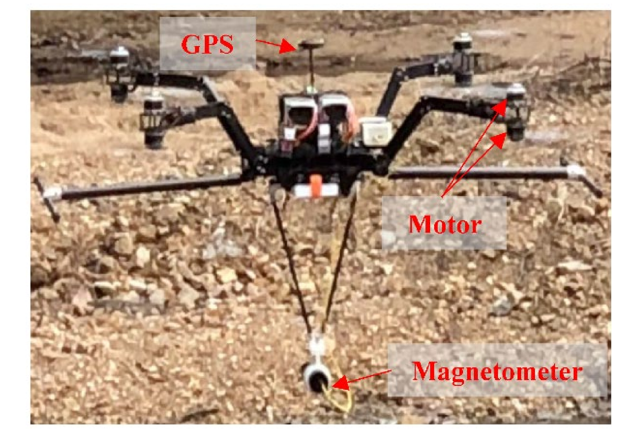
Smart rock (SR) with embedded magnet is designed to automatically roll down to the bottom of surrounding scour hole under strong current. Through remote sensing with a magnetometer and global positioning system (GPS) installed on a UAV, they can relate the maximum scour depth to the engineer in charge with the developed localization algorithm.

This research aims to:

- Develop and validate a remote sensing technology with SRs for real-time monitoring of scour during a flood event.
- Develop an unmanned aerial vehicle (UAV) based measurement of magnetic field for localization of SRs.

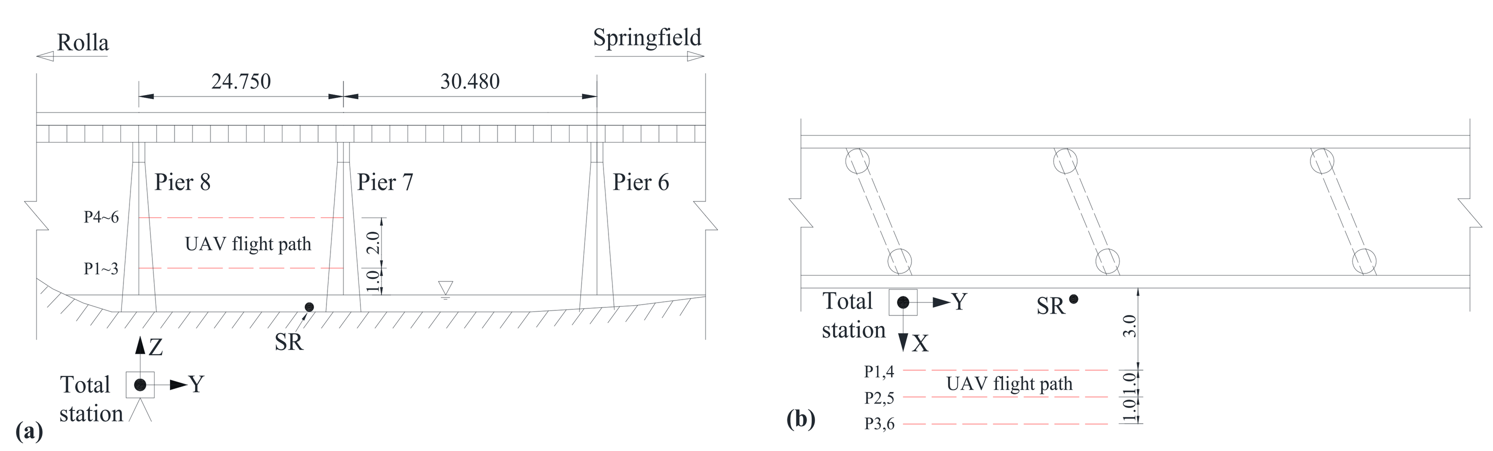


Schematic and deployment of SR



UAV for smart rock localization

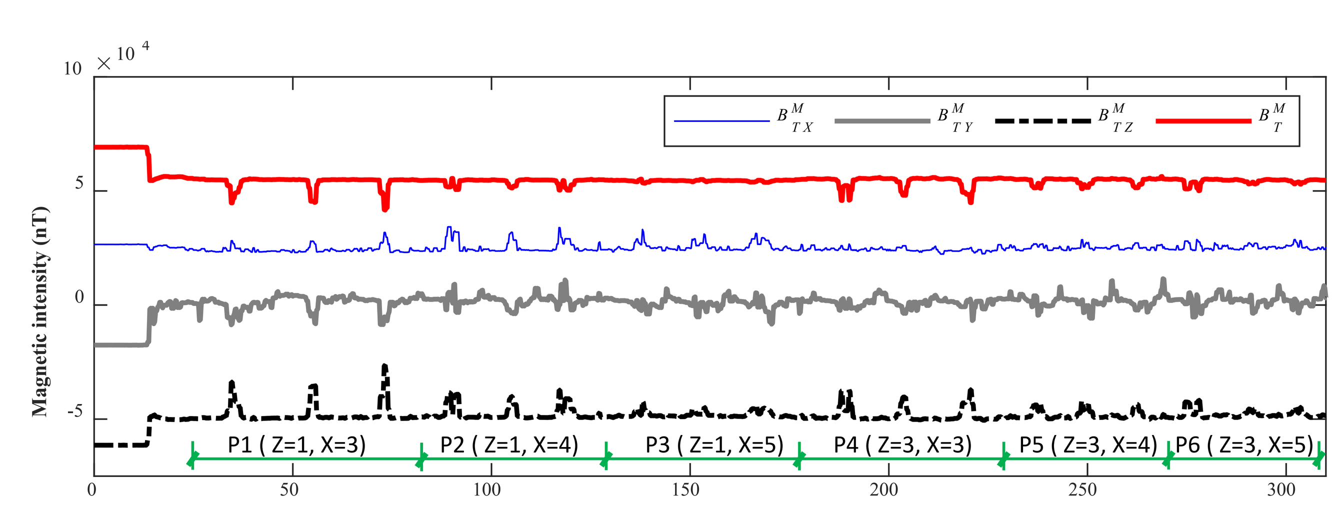
Field tests will be conducted every four month. For each test, the UAV flew at **two** altitudes of approximately 1 m and 3 m above water along six paths denoted by P1~6, as shown below. At each elevation, **three** paths (P1~P3 or P4~P6) were uniformly spaced with an interval of 1 m. Each path includes **three round trips** with a flight speed of less than 2 m/s.



UAV flight paths: (a) elevation view and (b) top view (unit: m).

RESULTS

As shown below, with the increase of horizontal or vertical distance between UAV and SR, the Z- component and total magnetic field, B_{TZ}^M and B_T^M decrease correspondingly. Since the X- and Y-components, B_{TX}^M and B_{TY}^M, are substantially less in magnitude than the Z-component B_{TZ}^M, the B_T^M intensity resembles very well the Z-component in magnitude.



The total magnetic field intensity and its three-component time histories

The coordinates predicted from the localization algorithm and measured from a total station are compared in following table. The difference in two measurements over time reveals the movement of the smart rock during that time period, with the vertical movement showing the depth development of a scour hole. Based on the smart rock movement between 6th and 7th field tests, the bridge scour depth dramatically increased by about 0.40 m during the **flood event** in February 2019.

It should be noted that the UAV-based monitoring system requires only little time to set up and no traffic control during scour monitoring.

Test Number	Test Date	Measured Coordinate			True Coordinate			Error (m)
		X_m	Y_m	Z_m	X_t	Y_t	Z_t	
4th	01/24/2018	0.02	23.50	-2.89	0.25	23.77	-2.93	0.36
5th	05/10/2018	0.49	25.00	-2.81	0.45	24.78	-3.01	0.30
6th	10/08/2018	0.43	25.07	**-2.76**	0.41	28.84	**-2.98**	0.32
7th	02/25/2019	0.37	25.60	**-3.16**	0.35	25.50	**-3.41**	0.28
8th	05/17/2010	0.43	24.00	-3.02	0.26	23.80	-3.17	0.30
9th	08/17/2019	0.41	23.32	-3.12	0.23	23.53	-3.22	0.29

CONCLUSIONS

- During a series of tests on about every four months, the UAV-based monitoring method leads to comparable results measured by total station, indicating the proposed method was validated.
- The smart rock deployed near Pier 7 of the Roubidoux Creek Bridge was located successfully and satisfactorily. The Smart Rock moved down the scour hole by about 0.40 m during the Feb. 25, 2019 flood event.

REFERENCE

G. Chen, Y. Tang, Y.Z. Chen, *et al*. "Smart Rock Technology for Real-time Monitoring of Bridge Scour and Riprap Effectiveness – Design Guidelines and Visualization Tools", Final Report submitted to USDOT/OST-R, December 31, 2016.

ACKNOWLEDGEMENTS

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