Verification Test of the In-situ EM sensor

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Cable-stayed bridges and suspension bridges are constructed to across a sea, a bay or a wide river. Their main span, the distance between supports of the bridge deck, is competitively increasing according to the development of structural analysis and construction technology. The longest is currently 1,991 meter that Akashi-Kaikyo suspension Bridge at Japan has the record. Regarding cable-supported bridges the most important parameters are the tension force to the cable. Therefore, the force should be monitored from during construction to the life cycle of cable.

The current popular method to measure the tension force of cable is the vibration method using accelerometer. The natural frequency of the cable is converted into the tension force after applying mathematical techniques such as FFT and the equation of motion for a string. Although this NDT method limits to a short cable, it is a quite accurate method and convenient to install a sensor. EM (Elasto-magnetic) sensor produced by Intelligent Instrument System, Inc. (IIS) is alternative to the vibration method, and it is a practical application of Faraday's law. EM sensor is based on the magnetic phenomenon that the permeability of ferromagnetic material is in proportion to the tension force.

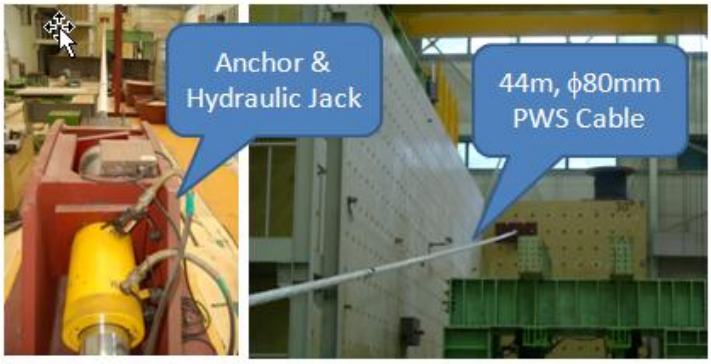

Fig.1 HDEC test bed and specimen

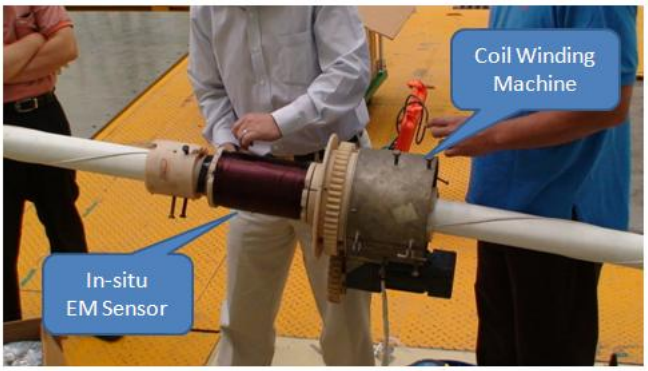

Fig. 2 Installation of in-situ EM sensor

IIS cooperated with the research institute of Hyundai Engineering and Construction, Ltd. (HDEC) had implemented the verification test of the in-situ EM sensor fabricated at HDEC's research facility at Korea on September, 2009. The parallel wired strand (PWS) cable of 44 meter long and 80 mm diameter installed to the reaction wall is the same size with one of original cables used in the Ma-Chang Grand Bride, cable-stayed bridge, opened on July 14, 2008. The in-situ EM sensor is fabricated at the arbitrary position over the polyethylene (PE) cover, and an accelerometer is located at a quarter positions. At the end of the cable a hydraulic jack and a load cell are attached to control and detect the tension force precisely. The applied maximum load of 735 kN is 42% to the allowable force of the cable, 1765 kN, for safety reason.

The two methods, vibration method and EM sensor, were evaluated with the readings from load cell. At 5% of the allowable tension force the two methods have a considerable difference with load cell. At the stage the sag of the cable was too large. However, these low stress states do not exist to a real cable-supported bridge. Both the methods are quite accurate from above the low stress.

Table 1. Comparison of vibration method and EM sensor

Load Cell		Vibration Method		EM sensor	
Force (kN)	Ratio (F_{LC}/F_{allow})	Force (kN)	Ratio (F_{VM}/F_{LC})	Force (kN)	Ratio (F_{EM}/F_{LC})
91.6	0.05	99.2	1.08	105.7	1.15
196.5	0.11	205.0	1.04	204.9	1.04
298.9	0.17	300.3	1.00	303.9	1.02
393.2	0.22	386.6	0.98	403.4	1.03
496.0	0.28	483.3	0.97	501.1	1.01
591.1	0.33	577.3	0.98	600.0	1.01
638.4	0.36	621.8	0.97	642.6	1.01
693.5	0.39	675.1	0.97	696.9	1.00
735.1	0.42	714.5	0.97	737.3	1.00

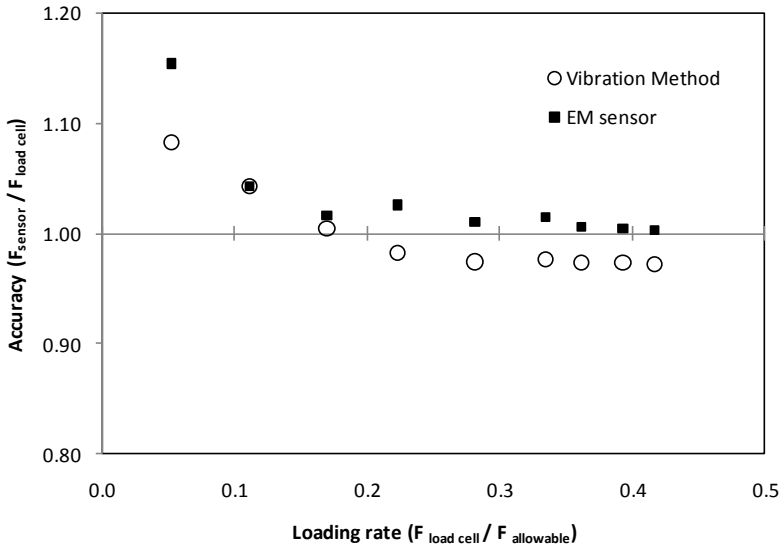

Fig. 3 EM sensor and vibration method

The in-situ EM sensor as a NDT technology is the novel monitoring device to measure cable force directly. For an actual size of a stayed cable bridge, EM sensor was fabricated and evaluated. EM sensor as an alternative to the vibration method has advantages that there is no limitation of geometric conditions such support conditions, length of cable, and sag effect, because the sensor relies on the material property itself on a certain point. At this verification test the accuracy of the EM sensor was better than the vibration method from above the 5% of the allowable force. However, the difference is negligible, and both are acceptable as an accurate sensor.