MOVEMENTS OF THE QUEBEC BRIDGE'S SUSPENDED SPAN MEASURED BY GNSS TECHNOLOGY

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The Quebec Bridge was completed in 1917 and it is still the longest cantilever bridge in the world. Overall, the actual movements of its suspended span, as detected by GNSS (between 2012 and 2013), are in fair agreement with the original design calculations: for the train loading effect on the vertical movement (17 cm for one freight train); the transversal wind load effect on the transversal movement (32 cm for a wind speed of 170 km/h); and the temperature loading effect on the vertical movement of the suspended span (3.2 cm for a 50°C temperature variation). Further movements have been detected by GNSS technology, namely: the transversal and longitudinal movements of the suspended bridge span due to train passages (11 cm transversally, at the top of the suspended span, and 1 cm longitudinally); the transversal movement of the bridge caused by solar radiation (differential) conditions on both sides of the bridge (5 cm for high solar radiation values); and the longitudinal movement of the suspended span of the Quebec Bridge at temperatures lower than 6°C (7 cm to −25°C).

La construction du pont de Québec a été achevée en 1917 et il est toujours le plus long pont cantilever au monde. Dans l'ensemble, les mouvements actuels de sa travée suspendue détectés par GNSS (entre 2012 et 2013) correspondent bien avec les calculs d'origine : pour l'effet de charge des trains sur le mouvement vertical (17 cm pour un train de fret); l'effet de charge du vent transversal sur le mouvement transversal (32 cm pour une vitesse de vent de 170 km/h); et l'effet de charge de la température sur le mouvement vertical de la travée suspendue (3,2 cm pour une variation de température de 50°C). D'autres mouvements ont été détectés par la technologie GNSS, à savoir : les mouvements transversaux et longitudinaux de la travée suspendue du pont en raison du passage de trains (11 cm transversalement, au sommet de la travée suspendue et 1 cm longitudinalement); le déplacement transversal du pont provoqué par les conditions du rayonnement solaire (différentiel) sur les deux côtés du pont (5 cm pour les valeurs élevées de rayonnement solaire); et le déplacement longitudinal de la travée suspendue à une température inférieure à 6°C (7 cm à −25°C).

Introduction

The origin of this project was to better establish the actual clearance of the Quebec Bridge, which crosses the St. Lawrence River near Quebec City, and to potentially increase the number of tall ships that can securely pass under the bridge and reach the Port of Montreal. For this purpose, the Montreal Port Authority installed a radar instrument under the structure of the Quebec Bridge to monitor the St. Lawrence River water level. This project was done in collaboration with the Canadian Coast Guard (CCG) and the Canadian Hydrographic Service (CHS), with the agreement of the Canadian National (CN) Railway Company, the owner of the Quebec Bridge. Furthermore, in order to take into account the movement of the installed radar, a GNSS antenna (Global Navigation Satellite Systems including the American GPS and the Russian GLONASS systems) connected to a GNSS receiver, was installed on top of the central suspended span of the bridge 34 m above the radar.

Although the original goal of the experiment was not dedicated to monitoring the 3D deformation of the Quebec Bridge, we asked to have access to the GNSS data collected on top of the Quebec Bridge's suspended span for analysis. This was an opportunity to monitor one of the most famous engineering structures in Canada built a century ago.

This paper contains the analysis of the 3D deformation of the Quebec Bridge's suspended span as measured by GNSS technology as functions of train and wind loads, along with the effects of temperature, including solar radiation. The next sections present a short description and the history of the Quebec Bridge and the equipment and data used to perform this analysis.

The Quebec Bridge

The Quebec Bridge (46° 45' N, 71° 17' W) is the first bridge over the St. Lawrence River encountered by ships travelling upstream from the Gulf of St. Lawrence and the Atlantic Ocean.

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