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EARTHQUAKES AND SEISMIC DESIGN FOR BRIDGES IN VIRGINIA

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Abstract

Virginia is located in a low to moderate seismic zone though big earthquakes do occur like the 5.8M event in 2011. Earthquakes in Virginia are felt as farther than the earthquakes that occur in West Coast because the unique geological features in East Coast. Research has been under way since the 2011 event to better understand the mechanism that causes earthquakes in Virginia. The seismic design for the highway bridges in Virginia is performed in accordance with the AASHTO LRFD Bridge Design Specifications. Seismic analysis may not be needed in the many areas in Virginia.

Keywords: Central Virginia Seismic Zone, jointless bridges, low to moderate seismic zone

1. Overview of Earthquakes in Virginia

Based on the theory of plate tectonics, Virginia is located in the middle of the North American plate; the nearest tectonic plate boundary is the Mid-Atlantic Ridge, in the middle of the Atlantic Ocean. Earthquake activity occurring away from plate boundaries is known as "intraplate seismicity". Such earthquakes are generally less severe and less damaging than those occurring at plate boundaries, such as California which is located on the boundary between two large blocks of the earth's crust, the North American and Pacific tectonic plates.

Earthquake activity in Virginia has generally been, with a few exceptions, low-magnitude but persistent. Since 1774, the year of the earliest documented Virginia earthquake, there have been over 300 earthquakes in the Commonwealth, shown as in Figure 1. Of those, 19 earthquakes had reports of intensity VI or higher. The largest documented earthquake in Virginia was the 1897 Giles County shock. The maximum intensity was VIII in Giles County, and it was felt over 11 states. The estimated magnitude for this event was 5.8 to 5.9, making it the third largest earthquake in the eastern United States in the last 200 years.

Virginia's past seismic activity is concentrated in three primary areas: the Central Virginia seismic zone (CVSZ), the Giles County seismic zone (GCSZ), and the Eastern Tennessee seismic zone (ETSZ). The CVSZ is located within the central Virginia, shown in pink in Figure 1. The GCSZ is along the New River Valley in Giles County, shown as the bigger blue cluster in Figure 1. The ETSZ stretches from northern Alabama and Georgia north through eastern Tennessee and includes a small portion of far southwestern Virginia.

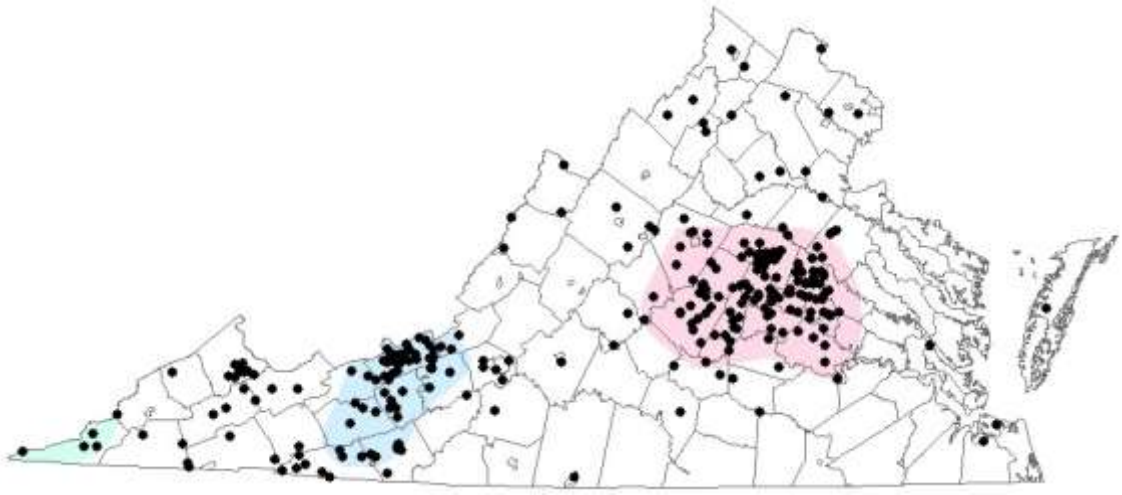

Figure 1. Major Earthquakes in Virginia

Earthquakes in Virginia usually occur at depths of anywhere from three to fifteen miles, while West Coast earthquakes can be very shallow and often break the ground surface. In general, East Coast earthquakes are less energetic than those on the West Coast, but due to the coherency of the basement rock they are felt much farther away. In Virginia, the affected area can be up to ten times larger than it would have been for a similar magnitude event occurring in the western United States. Figure 2 shows that the 2011 earthquake in Virginia was felt as far as in Canada.

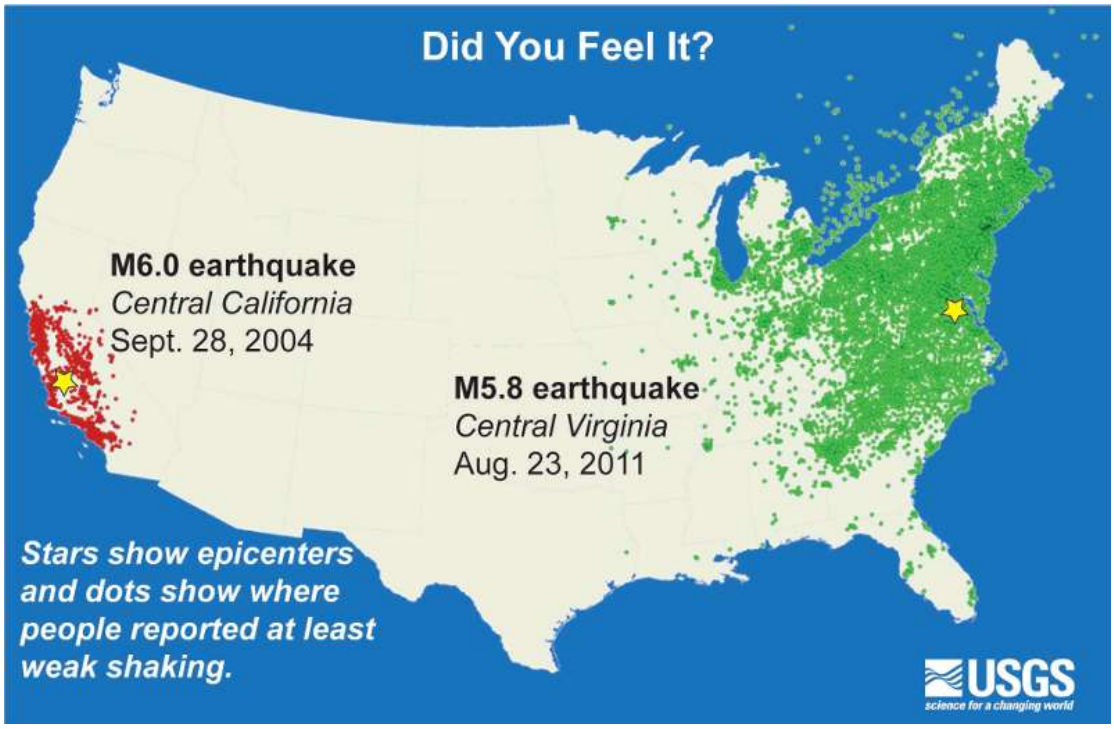

Figure 2. Map of Felt of 2011 Virginia Earthquake

2. The 2011 Earthquake in Virginia

A magnitude of 5.8 earthquake occured at 1:51 p.m. eastern daylight time on Tuesday, August 23, 2011 in Virginia. The epicenter of the quake falls within the Central Virginia Seismic Zone. This is the largest Virginia earthquake recorded by seismometers. The U.S. Geological Survey reported that this was the most widely-felt earthquake in U.S. history.

Fortunately, the event was centered in a rural area and did not cause widespread severe damage or serious injuries even though the presence of a large number of old, unreinforced masonry buildings in that area. However, moderately heavy damage did occur to schools, businesses, and homes in the epicenter area, see Figure 3. Damage in Louisa County alone where the epicenter was located was estimated to be more than $80 million.

Figure 3. A Carport Collapsed near the Epicenter

Widespread light-tomoderate damage occurred in the area from central Virginia to southern Maryland. In the nation's capital, there was damage to several landmarks including the Washington Monument, see Figure 4, and Washington National Cathedral. Damage to the Washington Monument and the Washington National Cathedral could cost $40 million to repair. The Washington Monument was closed for 3 years for repair.

Figure 4. Crack in the Washington Monument

The North Anna nuclear power station, located about 12 miles from the main shock epicenter, was shut down for 2.5 months as a result of strong shaking from the earthquake.

The highway bridges experienced some minor to moderate damages. No bridges or bridge components failed though some cracks or spalling occurred in several bridges, see Figure 5 to 7. It was believed that the light weight of the steel superstructure and regular layout and configuration of the bridges played a very important role for the good seismic performance.

Figure 5. Displacement of Bridge Rail

Figure 6. Damage in Bridge Seat

Figure 7. Crack in Column

Overall seismic performance of the highway bridges in Virginia was encouraging especially newly built jointless bridges.

3. Seismic Design of Bridges in Virginia

Seismic design of bridges in Virginia is performed in accordance with the AASHTO LRFD Bridge Design Specifications. Seismic design is required for all bridges in Virginia though the state of Virginia is located in a relatively low seismic hazard area. Most of bridges in Virginia are located in Seismic Performance Zone 1 unless the Site Class is E or F. Seismic analysis may not be needed in the many areas of Virginia. The connections between the bridge components are the critical areas for seismic design.

The jointless bridges including full-integral, semi-integral and Virginia Abutment are used in Virginia to the greatest extent possible. Research and past experience indicated that jointless bridges have good seismic performance.

4. Discussion

Virginia is located in a low to moderate seismic zone. The mechanism and patterns of earthquakes in Virginia are not clearly understood. Research is under way to better understand the geological and geophysical setting of the August 2011 earthquake in Virginia. New airborne geophysical surveys are collecting lidar, magnetic, gravity, and radiometric data in the epicentral region, and when combined with additional geologic fieldwork, scientists hope to develop an improved understanding of earthquake hazard along the eastern seaboard including Virginia. The research findings would influence the future seismic hazard maps.

New materials are encouraged to use in bridges in Virginia. Those include corrosion resistant reinforcing steel and prestressing strands such as stainless steel strands and carbon fiber reinforced polymer strands. Research is needed to better understand the seismic performance of the bridge components which are constructed with those materials.

5. References

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