The Design and Prototype Test for the Tunnel Foundation of High Energy Photon Source

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ABSTRUCT: HEPS is being built in China with challenging beam stability requirements. To fulfil the 25 nm ground motion restriction on the storage ring tunnel slab, two prototype slabs with different design schemes were constructed on the HEPS site. The first scheme adopted a 1 m reinforced concrete with replacement layer of a 1 m sand & stone underneath. The second scheme employed an extra 5 m grouting layer below the previously mentioned two layers. A series of tests had been carried out. The prototype slab with grouting layer is testified to have comparable vibration level with the bare ground, which is under 25 nm without traffic inside the HEPS campus, while the vibration level is amplified a lot on the other prototype slab. However, it is hard to make the grouting layer homogeneously under the kilometre-scale tunnel and besides the cost is unacceptable for 5 m grouting with such a large scale. The finalized design is fixed to be a 1 m reinforced concrete slab and 3 m replacement layer underneath using plain concrete. In this paper, the details of the prototype slab test results will be presented.

INSTRODUCTION: High Energy Photon Source (HEPS) is a 6 GeV, 1.3 km, ultralow-emittance storage ring light source to be built in Beijing, China. The designed natural emittance is about 35 pm. To ensure the stability of the beam on experimental station, the RMS displacement integration of vibrations on the slab has to be kept smaller than 25 nm over frequency range of 1 Hz up to 100 Hz. In order to fulfil this requirement, three more specifications are set up according to the ground motion level of HEPS site: 1) Ambient motions on the slab caused by internal and external vibration sources have to be smaller than 1 nm in all three directions; 2) No vibration amplification by the slab of the storage ring (RMS integral over frequency of 1-100Hz); 3) No vibration amplification by the pedestal-girder-magnet assembling.

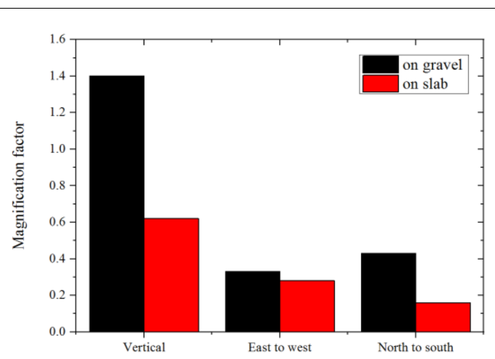
The first one will be realized by setting regulation plan to the transportation inside the HEPS campus and taking damping measures for the vibration utilities. And the Egan frequency of the pedestal-girder-magnet assembling is specified to be <54 Hz for achieving amplification factor closing to one. A well designed & made slab has no vibration magnification to the ground motions. To construct such a slab and finalize the slab design, two prototype slabs with different designs were constructed on HEPS site. The test results will be introduced in this paper.

PROTOTYPE SLABS

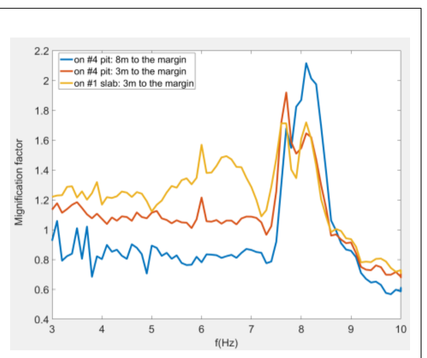
Schematic design of the two prototype slabs.

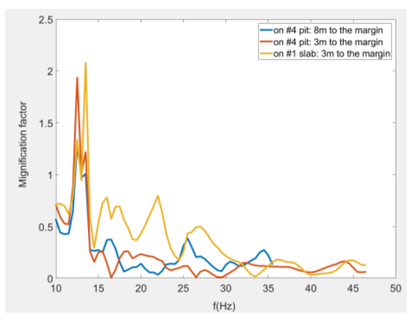
The prototype #4 slab: after grouting.

Slab #1 performance



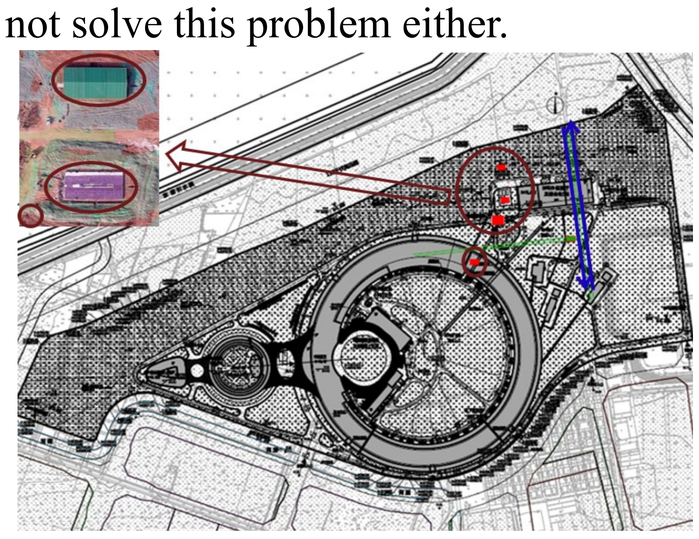
Performance comparing for Slab#1 & #4





There are two prototype schemes for slab #1 and slab #4, slab #1 has two layers with 1m of "sand and stone" (2nd layer) and 1m of "reinforce concrete layer" (3rd layer) on top. The 3rd layer has better performance than the 2nd layer. Slab #4 has an extra grouting layer from -2m to -7m (underground).

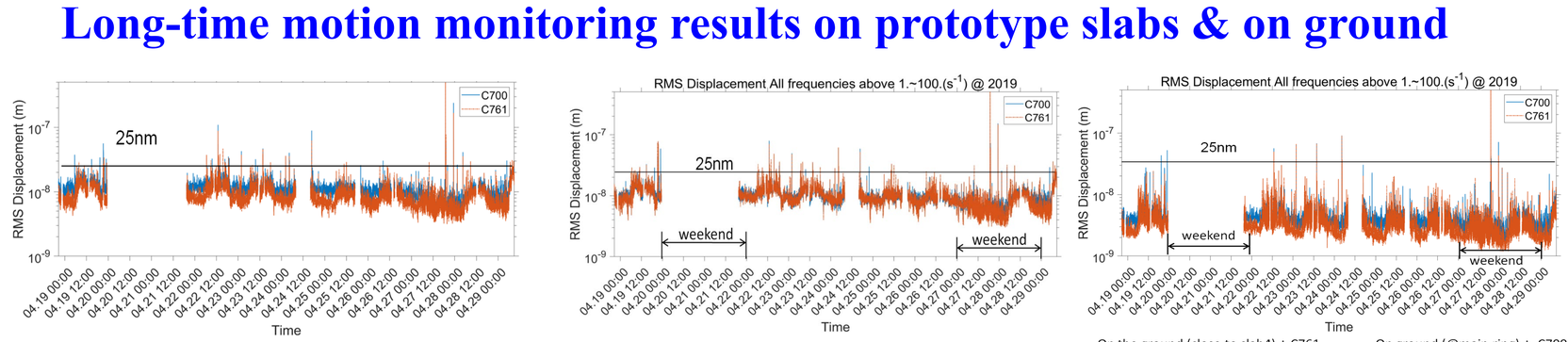
The noise level on grouting layer is already smaller than slab #1. For the noise level 8 meters away from the margin of grouting layer, the magnification factor is smaller than one for 1 Hz ~ 50 Hz, except 7-9 Hz and 10-15 Hz. The ground is sensitive to the vibrations of these frequencies, and grouting could not solve this problem either.



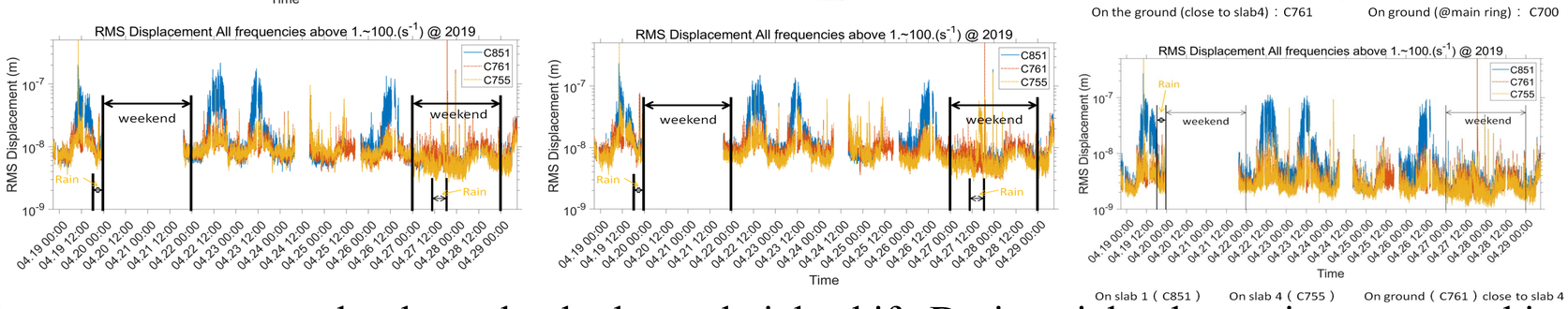
Long-time motion monitoring on prototype slabs & on ground: the four red squares are four monitor positions, the street where the blue arrows are is a municipal road inside the HEPS campus (it is closed now).

Long-time motion monitoring results on prototype slabs & on ground

On ground



On prototype Slabs



The measurement results show clearly day and night shift. During night, the motion on ground is about 4 nm & 10 nm (z & h). During day time, it is about 10 and 20 nm. For the slabs, during the weekdays, the vibration is amplified a lot on slab #1, while the prototype slab #4 with extra 5 m grouting layer has comparable vibration level with green field. However, considering the cost &construction difficulties, the grouting scheme is not adopted for the final foundation design.

Conclusion

In order to define the tunnel foundation of HEPS. Two prototypes of different design were constructed. The one with extra grouting layer has comparable noise with bare ground. Considering the cost and construction difficulty, the finalized design is fixed to be a 1 m reinforced concrete slab & 3 m replacement layer underneath using plain concrete which is verified by finite element analysis to be having equivalent effect as the grouting scheme.

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