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DYNAMIC EFFECTS ON CULVERTS FOR SEMI-HIGH SPEED TRAIN

Deepak Prasad[*1], Jyoti Yadav[*2]

[*1]M.Tech Scholar, Dept. Of Civil Engineering, Sarvepalli Radhakrishnan University, Bhopal, Madhya Pradesh, India.

[*2]Assistant Professor, Dept. Of Civil Engineering, Sarvepalli Radhakrishnan University, Bhopal, Madhya Pradesh, India.

ABSTRACT

In newer railway lines, culverts are fairly prevalent. This kind of partly submerged building often includes wildlife corridors and drainage channels. Their dynamic behavior has gotten significantly less attention than that of other buildings like bridges, but their sheer quantity makes this a fascinating subject from the standpoint of safety and cost savings. This presentation will give a comprehensive investigation of a culvert, including on-site measurements as well as numerical modeling. The construction is part of a semi high-speed railway line in Spain that connects Segovia and Valladolid. In 2004, the line was opened to traffic. It has the most common measurements (3x3m) along the line. Other variables, such as the low overburden (0.6m) and the almost right angle with the track axis, make it a useful example for drawing broad implications. On-site measurements were taken in the structure, capturing the dynamic response at various places during the passage of semi high-speed trains traveling at speeds ranging from 150 to 200 km/h. The measurements alone provide a solid idea of the structure's basic characteristics in terms of dynamic behavior. A three-dimensional finite element model of the structure was also investigated since it provides for a better understanding of the dynamic response to train loads. The disparities between projected and observed vibration levels will be examined in this work, and some numerical modeling recommendations will be made.

Keywords: Underpass, Dynamic Effects, And Semi High-Speed Train, Culverts, Corridors.

I. INTRODUCTION

Culverts and underpasses are prevalent on modern railway lines, especially semi high-speed lines (SHSRL). This kind of partly submerged building often includes wildlife corridors and drainage channels. They are not basic structures, according to Eurocode, for which the impact factor may be calculated using simpler methods. As a result, the amount of study necessary in their design is comparable to that required in the design of non-traditional bridges, yet their cost should be orders of magnitude lower. The Spanish Public Works Office is addressing this inconsistency in cost and design effort. The dynamic reaction of a group of genuine buildings in the SHSRL between Two stations was observed as a first step. A preliminary set of this work's findings has already been published [1], [2]. This research focuses on one of these formations, whose dimensions are rather common. The structure and arrangement for monitoring are presented in the first section of this study. Also described will be the most essential elements of the recordings made during the passage of a series of semi high-speed trains. The structure was modeled using finite element (FE) methods to get insight into its dynamic behavior. A pair of two FE models, one representing the superstructure and the other representing the structure, the embankment, and a piece of the soil, will enable simulations to be run and time histories of various response parameters to be estimated. The second portion of the study will address all difficulties relating to FE models that are different from those previously utilized by some of the writers [3].

II. LAYOUT AND PRESENTATION OF STRUCTURE

The cross-section of the structure chosen for monitoring is square. It has a 3m-wide inner aperture and 0.2meter-thick walls. It is made up of eight precast blocks, each measuring 2 meters in length. As a result, the structure's entire length is 16 meters. The average distance between the ballast base and the structure's top plane is 0.6m. According to the available geotechnical data, the soil is granular and medium density. In a conventional SPT test, the number of strikes varies practically linearly from 10 at 1m deep to 90 at 5m depth. According to a statistical examination of all culverts and underpasses along the SSHSRL between Segovia and Valladolid, these dimensions were the most prevalent. The choice of structure is influenced by three major considerations. It is practically perpendicular to the track axis, for starters. Second, it lowered the amount of overburden. Third, the topographical qualities of the area provided for both appropriate access and adequate vision of trains operating on the route.

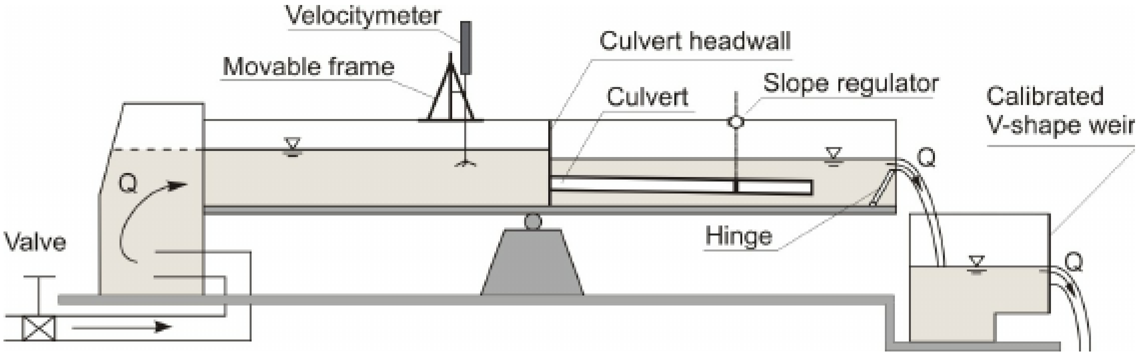

Fig.1: Layout Model of culverts

Piezoelectric accelerometers were used to monitor both the structure and the superstructure. Six sensors were installed in the center area of three separate precast blocks of the construction. A sensor has been placed vertically at the halfway of the roof and horizontally at the mid-height of the wall in each location. Figure 1 depicts the relative distances between sensors and the track axis. Sensors have been installed vertically on sleepers (near the external rail-pads) and the rail foot in the superstructure (at mid-span between two sleepers). Two sleeper and rail sensors have been installed on each track, for a total of four sensors. One sleeper is situated roughly above the underpass mid-span in each instance, while the other is three sleepers to the north. Only readings from three sensors (A, B, and C in Figure 1) will be considered in this article, which will concentrate on the dynamic behavior of the underpass roof.

III. MONITORING OF STRUCTURE

For a little more than 24 hours, the structure was observed. During that period, 46 trains passed through the station. The route was serviced by four distinct passenger trains. Depicts their nominal axis loads and distances. A sample of the recording was obtained. It was acquired during the passing of an s-130 train, which is the RENFE code for Talgo 250, at a speed of 200 kilometers per hour. There are two methods for estimating speeds. To begin, video records of the trains during the testing were used. Second, in root mean square (RMS) acceleration recordings, time-lapses between peaks associated with each axis are measured. Depending on the sensor, acceleration records indicate significant variances in observed values. The largest reaction was detected near the structure's center in this example. The energy in this signal is distributed across a large range between 0 and 120Hz, according to spectral analysis. The decay component of the record has a free vibration frequency of about 40Hz, according to the analysis. This is significant since EC0-A2 [4] specifies that peak acceleration levels must be computed using frequencies less than 30Hz, or 1.5 times the fundamental mode and the third vibration mode. It is difficult to determine the vibration modes of the ensemble structure - embankment in this example. It is evident, however, that there is a significant quantity of energy above 1.5*40=60Hz. a summary of all metrics taken. It displays the peak acceleration value for each sensor as a function of train speed for each sensor. For each train type, different symbols (circles, squares, stars, and diamonds) were employed. Additionally, distinct colors were utilized for each sense track. This is understandable given that trains nearly always run at their maximum speed. The dispersion in peak acceleration values seems to be crucial when considering each set of comparable samples of a particular train at a given speed. It's also obvious that track, or circulation, has a role in the reaction level. As will be shown, the variations are explained by the relative distance between the sensor and the track. The relative distances between the sensor and the circulating track vary depending on the perception of circulation. If this relative distance is taken into account, measurements acquired from both sensations of circulation may be examined together. Because the center sensor is not symmetrically situated, as illustrated, the number of potential places grows when relative distances are considered. Along with the ceiling of the underpass, a plot of peak vertical acceleration as a function of relative sensor location. Only s-130 trains traveling at roughly 200 km/h were examined to remove all other sources of

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dispersion. Each sense of circulation has been represented in a separate hue, by labeling. Both sensations of circulation lead to equal acceleration levels at locations 5m, as seen in the diagram. As a result, the significance of relative location in explaining response values is shown noteworthy because it demonstrates the uneven distribution of acceleration response along the underpass axis' central plane. Demand is higher below the circulating track than it is above the opposing track. The next part goes through the FE models that were created to provide a more thorough picture of the response levels along the roof.

IV. METHODOLOGY

A two-step procedure will be used to anticipate vibration levels at various sites across the building. First, reaction force records at the ballast-sub ballast interface will be assessed at discrete sites along the track axis for a particular train and speed. In the second calculation phase, when the acceleration record at the location of interest is produced, these points will be treated as source terms. This is done by considering as many transfer functions as there are source points. A finite element model representing half of the railway superstructure is used in the first stage. Beam components are used to depict the rail in this model. Sleepers are represented as lumped masses in the model. Both the fastening system and the ballast-embankment ensemble are modeled using spring dashpot components. The unsparing mass of half an axle is represented by a lumped mass that moves with the train's speed. To mimic touch, a spring dashpot element is employed. This mass is coupled to a moving load that represents axle load. The motion equation's time integration permits response force histories to be obtained at discrete places along with the ballast sub-ballast interface. Because all of the variables are linear, scaling may be used to produce time histories for various axle loads. Furthermore, time delays may be calculated using axle lengths and train velocity, allowing for the construction of a comprehensive history of reaction forces as the train passes.

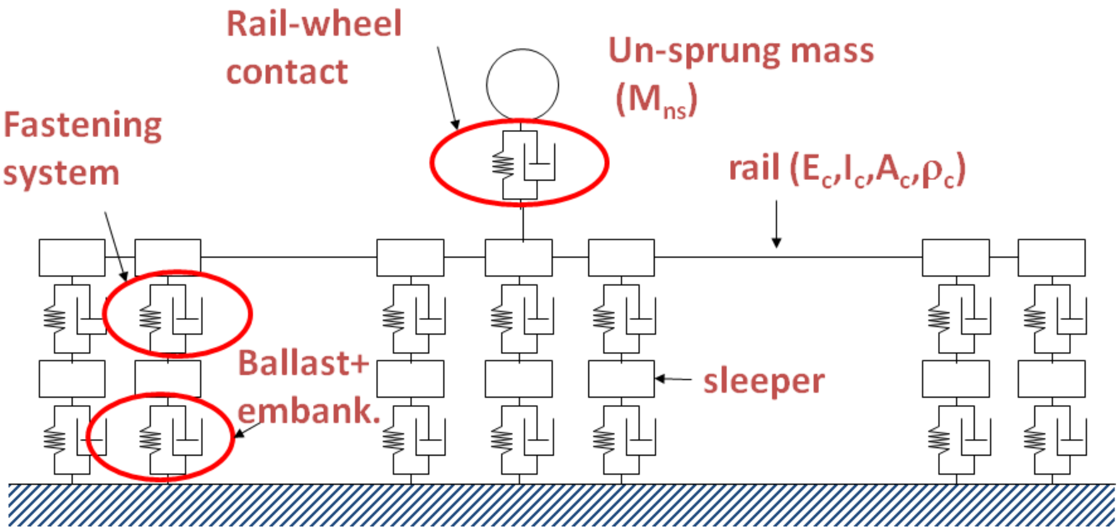

Fig.2: For calculating reaction forces at interface locations underneath each sleeper,

A finite element model was utilized

The following profile was used to describe rail roughness using the Braun & Hellenbroich spectral density model [5]:

$$G_{rr}(n) = G_{rr}(n_0)\left(\frac{n}{n_0}\right)^{-\omega}$$

Where no=1/2 and =3.5 are constants. A moving self-equilibrated pair of reaction forces may be defined from this profile, taking into account the train speed and the parameters of the contact element. This pair is taken into account in a second-time history analysis, allowing for the creation of new reaction force histories. Because this contribution to reaction force is independent of axle weight, when constructing the whole time history of reaction forces created by rail roughness as the train passes, only time delays must be included. The total response force histories at each position of the ballast-sub ballast contact may be obtained by adding these data

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to previous ones. In the second stage, transfer functions from the force at each emitter point of the ballast-sub ballast interface and acceleration at the reference point are considered in the frequency domain. Two emitter spots have been explored for each sleeper, one below each rail. Each rail is believed to contribute exclusively to the emitter point closest to it. Harmonic analysis using a finite element model of the culvert, embankment, and ground is used to calculate transfer functions. Using the reciprocity principle, all transfer functions are computed concurrently for a given frequency. At the node where the desired response is wanted, a unitary force is applied, and displacements are measured at all source locations. Only one-half of the geometry is represented due to the problem's symmetry. Figure 3 shows the mesh of the model. The soil, embankment, backfill, ballast, and concrete are the five distinct materials that have been specified. The hue of the elements in Figure 3 is determined by the substance they are made of. It has 20 node solid components and dashpots in the boundary properties to prevent incident waves from being reflected. The mesh has been created using 10 node tetrahedra in certain areas of the backfill. Harmonic analysis using a finite element model of the culvert, embankment, and ground is used to calculate transfer functions. Using the reciprocity principle, all transfer functions are computed concurrently for a given frequency. At the node where the desired response is wanted, a unitary force is applied, and displacements are measured at all source locations. Only one-half of the geometry is represented due to the problem's symmetry. Figure 3 shows the mesh of the model. The soil, embankment, backfill, ballast, and concrete are the five distinct materials that have been specified. The hue of the elements in Figure 3 is determined by the substance they are made of. It has 20 node solid elements and dashpots in the boundary properties to prevent incident waves from being reflected. The mesh has been created using 10 node tetrahedra in certain areas of the backfill.

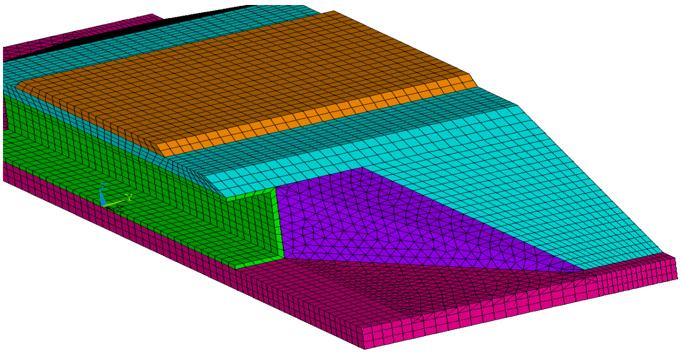

Fig.3: The transfer functions were obtained using a FE mesh.

V. ANALYSIS AND RESULT

With the embankment as the softest part, element sizes have been adjusted such that there are at least 4 elements per wavelength at 120Hz. The model's degrees of freedom have been restricted to allow the computer to solve the issue using just RAM (the computer machine used in calculations has 4 GB). Otherwise, the amount of time it takes to compute grows considerably. The model is 15.5m long on both sides and 10.8m long in the direction of the track axis, with 1 million degrees of freedom. Simulations have been run using the two models presented earlier. Graph Figure 4 compares one set of records to models for an s-130 train traveling at 200 km/h. RMS values are used to make comparisons (1s windows). There are two reasons for selecting the later value for comparisons. To begin with, peak acceleration is largely reliant on the signal's high-frequency content, and the simulations contain energy up to 120Hz. Second, peak values are often associated with extremely nonlinear events such as wheel-on-rail shocks, which are not modeled. Although no FEM settings have been adjusted, the agreement is fairly excellent.

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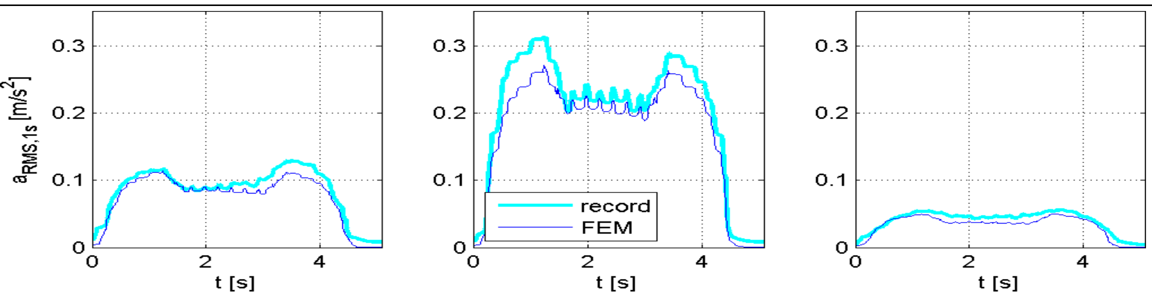

Fig.4: Simulations and records compared. S-130 train, v=200 km/h

More simulations have been run to evaluate the reaction in areas where no data have been taken. Measurements for s-130 trains traveling at 200 km/h are compared to forecasts at the mid-points of each pre-cast block in Figure 5. To determine an upper and lower limit for the response, predictions were made using two alternative roughness levels. In the Braun and Hellenbroich model, the lower limit is connected with the lowest roughness level (highest quality) in this example. An intermediate roughness level is connected with the top limit.

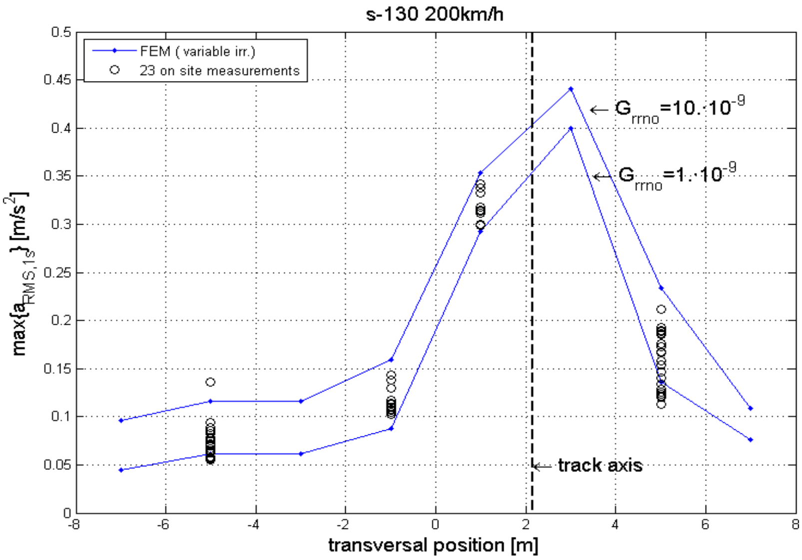

Fig.5: shows the comparison between simulations and measurements at the roof's midline

VI. CONCLUSION

- This paper gives a collection of data and models that may be used to deduce the dynamic behavior of common underpasses.
- Acceleration scatter is a significant factor, according to measurements. In addition, the response distribution along the underpass axis was found to be non-uniform, with the relative location of the track axis and the sensor being crucial.
- Using a set of two models: one for the superstructure and another for the ensemble structure-embankment-soil, finite element methods were used to predict the dynamic behavior of this construction. These models allowed for a comprehensive analysis of the response distribution throughout the structure's top plane.

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