AECOM DIN 01750

Effects of Light Rail Transit Ground Vibrations on the Southern Railway Bridge over Roxboro Street, Durham, NC

Durham-Orange Light Rail Transit Project

July 2015

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List of Acronyms and Abbreviations

Acronym/Abbreviation	Definition
D-O LRT	Durham-Orange Light Rail Transit
FTA	Federal Transit Authority
LRT	light rail transit
VdB	Measure of Vibration (micro inch/sec)

Executive Summary

The downtown Durham alignment of the Durham-Orange Light Rail Transit project (D-O LRT) takes the tracks in close proximity to the south side of the Southern Railway Bridge over Roxboro Street. A concern was raised that the close proximity of the light rail transit (LRT) tracks to the southwest wing wall of the bridge may have a detrimental impact on the wing wall of this bridge which was constructed in 1929 and is currently listed in the National Register of Historic Bridges.

The centerline of the westbound LRT tracks pass within approximately six feet of the southwest corner of the curved southwest wing wall. The center line of the current freight rail track is approximately 22 feet from the start of the wing wall at the keyed joint between the bridge and the wing wall.

Based on the Federal Transit Authority's (FTA) *Transit Noise and Vibration Assessment Guidelines*, the potential ground induced vibrations from the LRT measure approximately 82 VdB versus 90 VdB for the freight rail assuming both are traveling at 50 miles per hour. In comparison with the potential 82 VdB from the LRT, the ground borne vibration level of rubber tired vehicles (cars, trucks, buses, etc.) passing within a similar distance measures 75 VdB. To produce a comparable level of vibration to that induced by the LRT, the freight train track would need to be located at nearly four times the distance away from the wall compared to where the tracks are actually located.

Based on this information and the generally satisfactory structural condition of the wing walls, the presence of the LRT should have far less potential impact on the wing wall nearest the LRT track than the freight and passenger rail that has been operating in one form or another on this structure since 1929.

1. Introduction

The downtown Durham alignment of the Durham-Orange Light Rail Transit project (D-O LRT) takes the tracks in close proximity to the south side of the Southern Railway Bridge over Roxboro Street (see location map, Appendix A). A concern was raised that the close proximity of the light rail transit (LRT) tracks to the south side of the bridge may have a detrimental impact on the southwest wing wall of this historic bridge which was constructed in 1929 and is currently listed in the National Register of Historic Bridges.

The Roxboro Bridge consists of two reinforced concrete abutments with flanking wing walls on the south side of each abutment which support a reinforced concrete superstructure that appears to have been constructed using pre-cast slab units. The wing walls are attached to the abutment through a keyed cold joint. Due to the variation in depth of the bearing layer of the soil or rock, approximately half of structure is supported on spread footings, on the southern end, while the northern half of the structure is supported on piles. The bridge plans have been provided in Appendix B for reference.

1.1 Data Collection

On July 14, 2015, two engineers from AECOM traveled to the Roxboro Bridge to perform a visual evaluation of the condition of the bridge overall and specifically of the southwest wing wall.

The structural integrity of the bridge itself was not fully investigated during this visit. As can be seen in the image in Figure 1-1, there is significant damage to and spalling of the bottom of the reinforced concrete columns observed to be around 6 inches deep.

Figure 1-1 Spalls at base of columns and vehicle impact damage to fascia beam

The primarily visual inspection focused on the wing wall on the southwest corner of the bridge adjacent to Pettigrew Street. As indicated in Figure 1-2, there is map cracking up to 1/8 inch in width over the entire surface of the wall although most of the cracking is hairline or 1/16 inch in width. It is not uncommon to find this kind of pattern cracking on the surface of older reinforced concrete walls and is not an indication of a reduction in the structural integrity of the wall. This wing wall is more than 80 years old and appears in satisfactory condition considering its age.

Figure 1-2 Map cracking on southwest wing wall

Figure 1-3 shows a spall located at the joint between the abutment and the reinforced concrete wing wall measuring 12 inches wide by 6 feet tall and up to 3 inches deep. Reinforcing steel was exposed and some corrosion was evident. The presence of loose aggregate may indicate poor consolidation of the concrete during construction which caused the local defect that ultimately led to this face concrete spall. No other significant damage was observed along the exposed area of the wing wall.

The Southern Railway Bridge design drawings are attached as Appendix B and indicate the wing wall rests on a spread footing extending at least 12 inches beyond the wall at the base. To estimate the depth of the spread footing supporting the wing wall, a small area of soil along the corner of the wall was located which was suitable to probe. A clear obstruction was found at a depth of 35 inches below the soil that appeared to be the top of the concrete footing. Without excavation or test holes, the top of footing depth cannot be assured.

Figure 1-3 Spall at abutment joint with southwest wing wall

Figure 1-4 Probe used to estimate spread footing depth

2. Comparison of Freight Rail and LRT Vibrations

The FTA *Transit Noise and Vibration Assessment Guidelines* provide a general means to compare the intensities and potential impacts of different levels of ground borne vibrations such as those caused by moving freight trains, light rail trains and larger street running vehicles like trucks and buses at varying distances from a location or structure of concern. These guidelines were used to compare the intensity and potential impacts of ground borne vibrations from the LRT to the intensity of the vibrations from the existing freight rail and thus their relative effects on the referenced southwestern wing wall.

Based on survey information, preliminary LRT track plans, and photogrammetry of the Roxboro Bridge site, the distance between the centerline of the closest LRT track and the wing wall southwest corner is a little more than 6 feet – See Appendix A. The centerline of the freight rail track is approximately 22 feet from the joint between the abutment and the southwest wing wall. With this information, a comparison can be made between the relative intensities of ground borne vibrations induced on the wing wall by the LRT and freight rail, respectively.

Plotting the relative distances of each rail line on Figure 10-1 of the FTA *Transit Noise and Vibration Assessment Guidelines*, one can observe that the freight train vibration intensity is approximately 90 VdB at the wing wall (red line) whereas the LRT vibration intensity (blue line) is approximately 80 VdB. Thus the lower magnitude vibrations of the LRT on the wing wall are equivalent to a freight train at a distance of 80 feet from the wing wall. The LRT passing in close proximity to the wing wall therefore has less impact than the freight rail trains which have been operating on the Roxboro Street Bridge for over 80 years.

Figure 2-1 Reference Figure 10-1 from the FTA Transit Noise and Vibration Assessment Guidelines

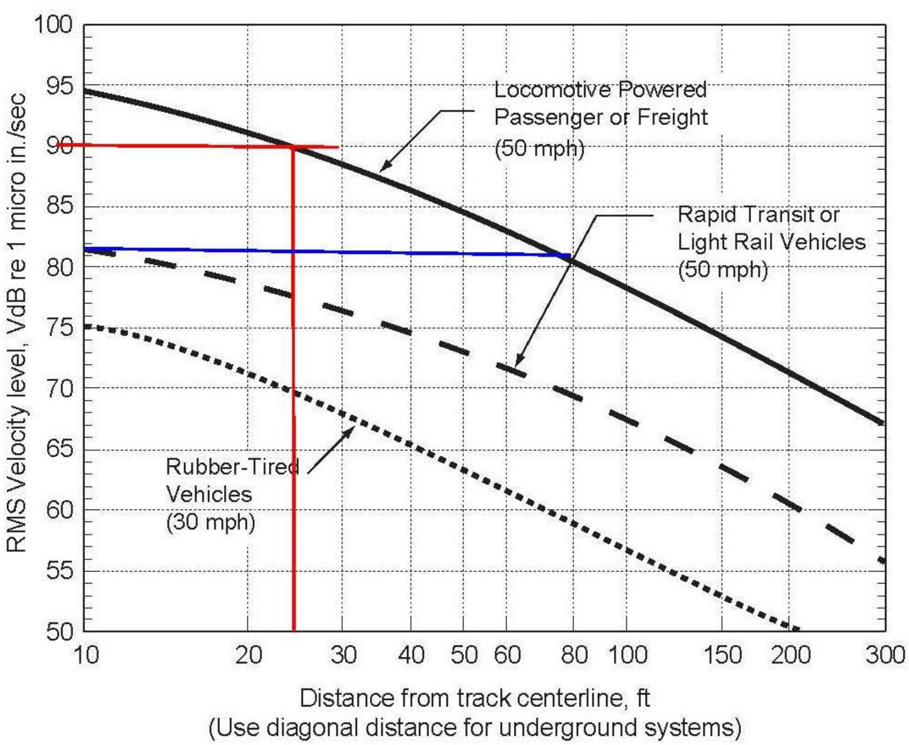


Figure 10-1. Generalized Ground Surface Vibration Curves

To put the level of ground borne vibration intensity in perspective, Figure 2-2, which is an excerpt from the FTA guidelines (Figure 7-3), shows the impacts that typical levels of ground borne vibration have on the nearby area. As noted in this figure, the velocity level of ground borne vibrations impacting a structure must be 100 VdB to reach the threshold to cause even minor cosmetic damage. Neither the LRT nor the freight rail vibrations approach this level. Therefore, based on the typical conditions encountered within a transit project, there should be no negative impact to the Roxboro Street rail road underpass due to ground borne vibrations. It is, however, recommended that a thorough geotechnical investigation be performed during final design to ensure that no geological special conditions or properties exist that could intensify ground borne vibrations beyond what has been presented herein.

Figure 2-2 Reference Figure 7-3 from the FTA Transit Noise and Vibration Assessment Guidelines

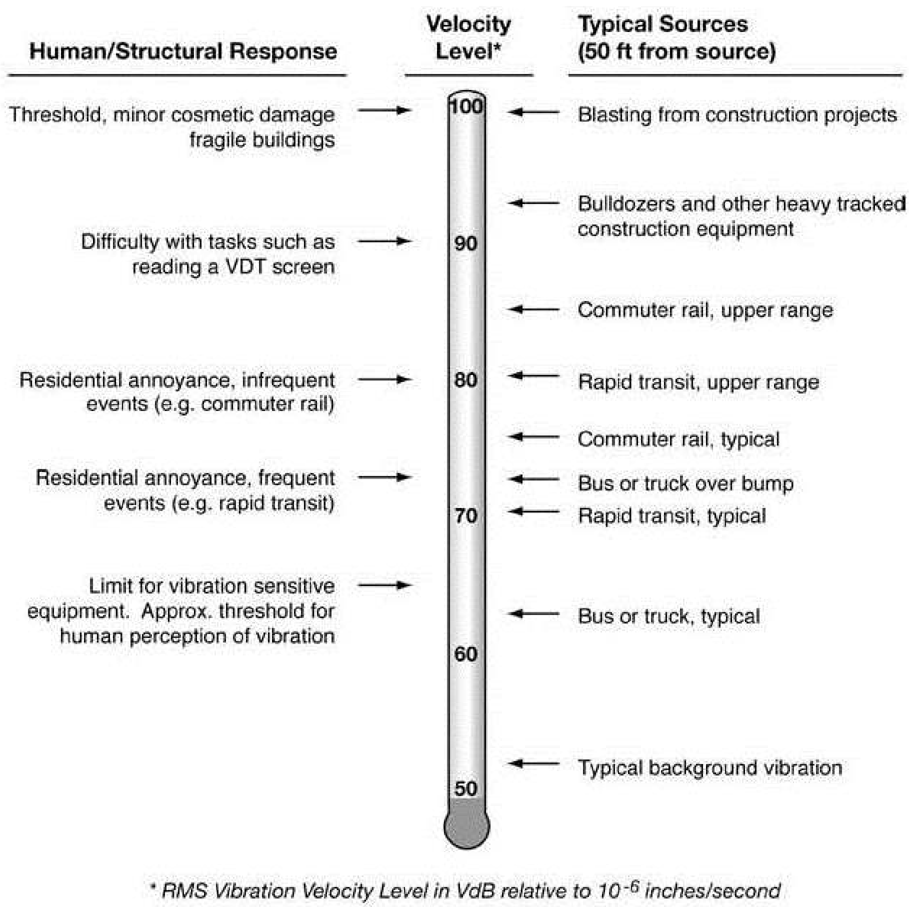
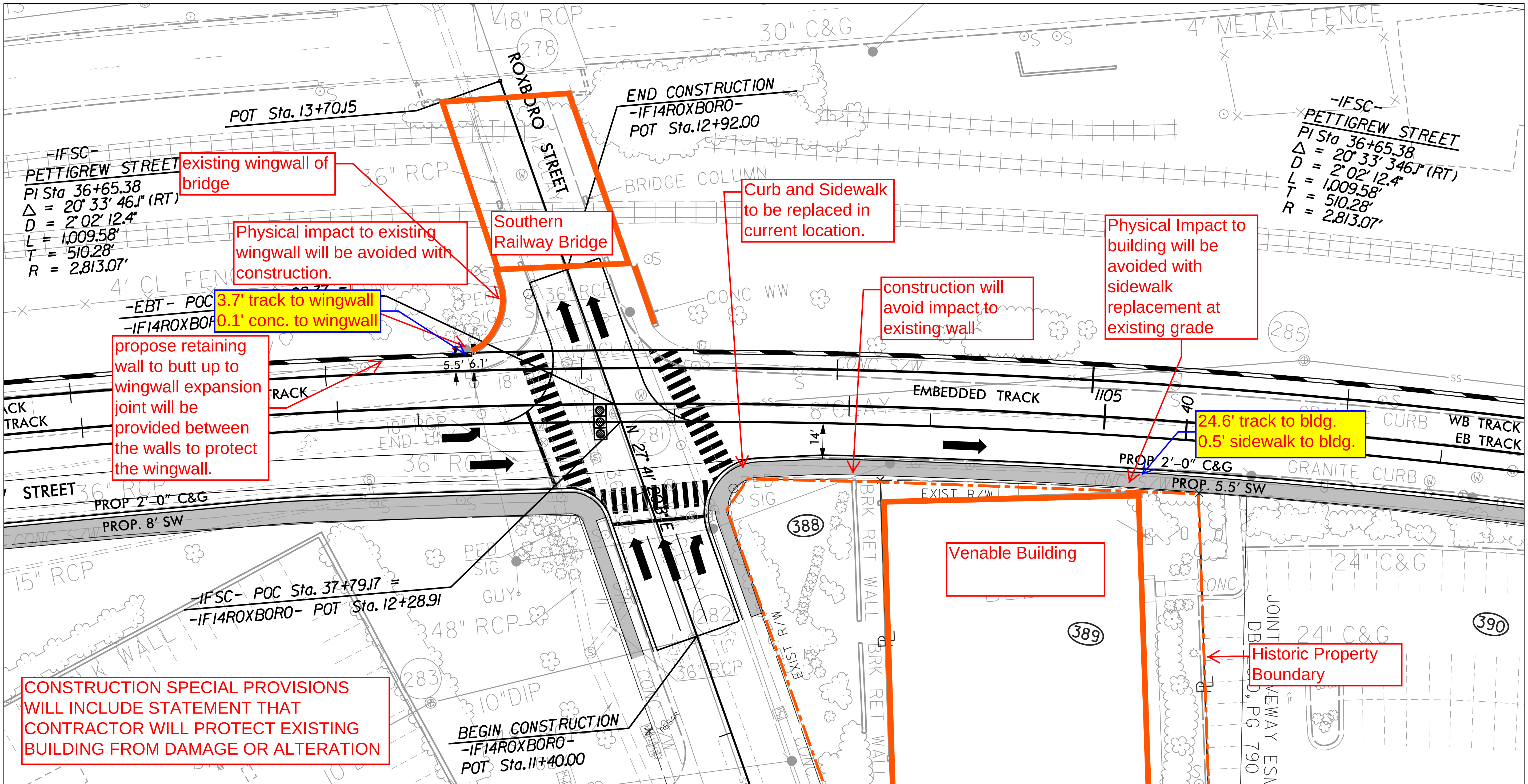


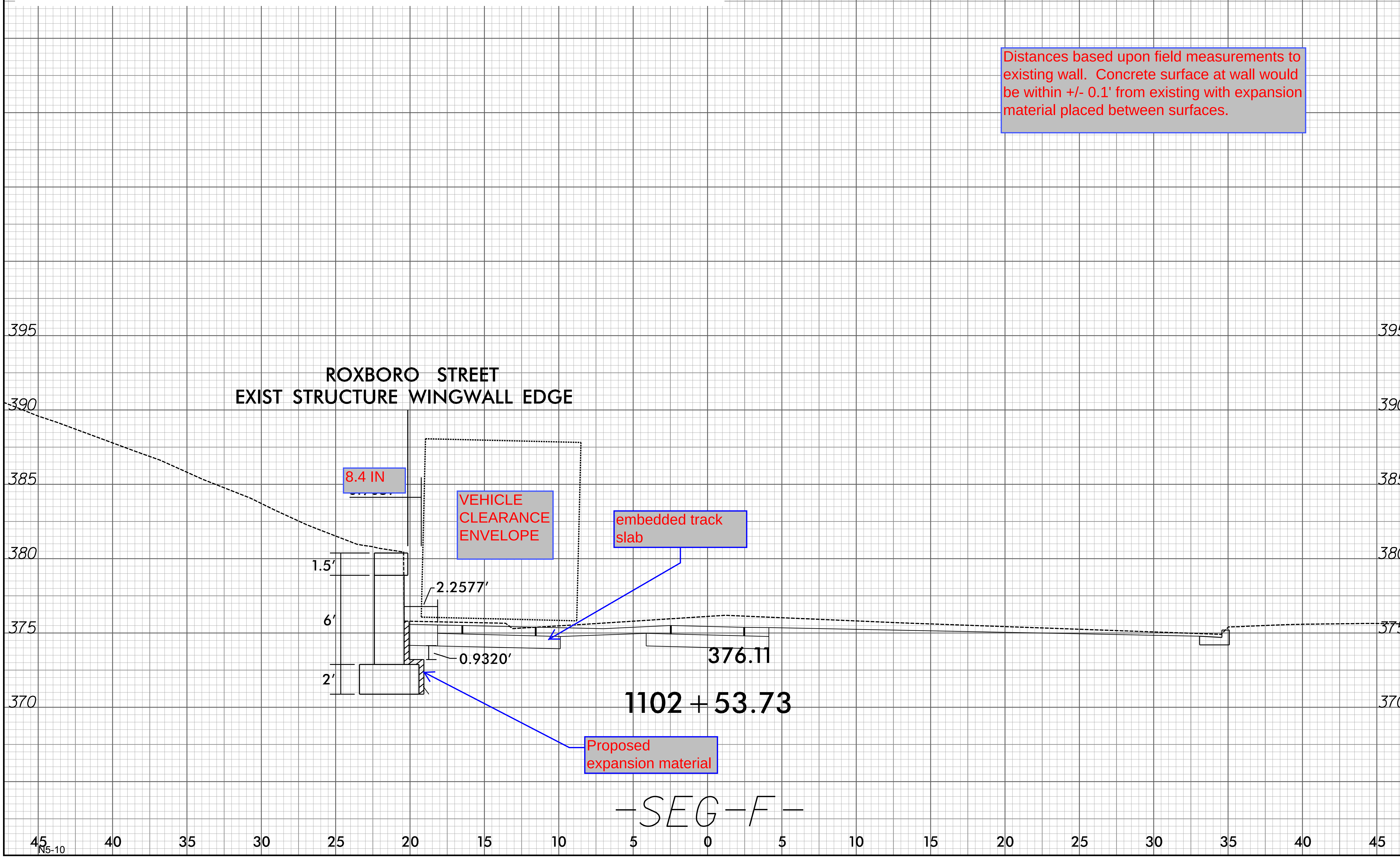
Figure 7-3. Typical Levels of Ground-Borne Vibration

APPENDIX A - LOCATION MAP

Effects of Light Rail Transit Ground Vibrations on the Southern Railway Bridge over Roxboro Street



APPENDIX A- CROSS-SECTION OF PROPOSED LRT AT EXISTING WING WALL
Effects of Light Rail Transit Ground Vibration on the Southern Railway Bridge over Roxboro Street



APPENDIX b EXISTING ROXBORO BRIDGE PLANS
Effects of Light Rail Transit on Southern Railway Bridge over Roxboro Street in Durham, NC

BILL OF REINFORCING STEEL FOR STRAIGHT WING							
Mark	No.	Size	Length	Mark	No.	Size	Length
Swa8	6	7/8"φ	15'-6"	Swc11	5	3/4"φ	7'-9"
Swa9	6	7/8"φ	13'-6"	Swc12	5	3/4"φ	7'-3"
Swa10	6	1/2"φ	11'-6"	Swc13	4	1/2"φ	7'-0"
Swa11	6	1/2"φ	9'-6"	Swc14	4	1/2"φ	6'-6"
Swa12	6	1/2"φ	8'-0"				
Swa13	4	1/2"φ	6'-6"	Swd8	5	3/4"φ	10'-9"
Swa14	5	1/2"φ	5'-0"	Swd9	5	3/4"φ	9'-9"
Swb5	6	1/2"φ	19'-0"	Swd10	5	3/4"φ	9'-0"
Swb6	3	1/2"φ	17'-0"	Swd11	5	3/4"φ	8'-0"
Swb7	2	1/2"φ	14'-0"	Swd12	5	3/4"φ	7'-3"
Swb8	3	1/2"φ	10'-9"	Swd13	4	1/2"φ	6'-6"
Swb9	2	1/2"φ	7'-6"	Swd14	4	1/2"φ	5'-9"
Swc8	5	1"□	9'-0"	Swe1	4	1/2"φ	20'-0"
Swc9	5	1"□	8'-6"				
Swc10	5	3/4"φ	8'-0"				

BILL OF REINFORCING STEEL FOR CURVED WING.							
Mark	No.	Size	Length	Mark	No.	Size	Length.
Cwa8	6	7/8"φ	17'-6"	Cwb6	2	1/2"φ	31'-6"
Cwa9	6	7/8"φ	16'-6"	Cwb7	3	1/2"φ	26'-0"
Cwa10	6	7/8"φ	15'-6"	Cwb8	2	1/2"φ	20'-0"
Cwa11	6	7/8"φ	14'-6"	Cwb9	3	1/2"φ	14'-6"
Cwa12	6	1/2"φ	13'-6"	Cwb10	2	1/2"φ	8'-6"
Cwa13	4	1/2"φ	12'-6"	Cwc8	20	1"□	9'-6"
Cwa14	6	1/2"φ	11'-6"	Cwc9	15	3/4"φ	9'-0"
Cwa15	6	1/2"φ	10'-6"	Cwc10	15	3/4"φ	8'-0"
Cwa16	6	1/2"φ	9'-6"	Cwc11	10	1/2"φ	7'-6"
Cwa17	6	1/2"φ	8'-6"	Cwc12	13	1/2"φ	6'-9"
Cwa18	6	1/2"φ	7'-6"	Cwd8	20	3/4"φ	12'-0"
Cwa19	5	1/2"φ	6'-6"	Cwd9	15	1/2"φ	10'-9"
Cwa20	6	1/2"φ	5'-6"	Cwd10	15	1/2"φ	9'-3"
Cwa21	7	1/2"φ	4'-6"	Cwd11	10	1/2"φ	8'-0"
Cwb4	13	1/2"φ	22'-6"	Cwd12	13	1/2"φ	6'-3"
Cwb5	3	1/2"φ	18'-0"	Cwe3	8	1/2"φ	26'-0"

BILL OF REINFORCING STEEL FOR ABUTMENT "A"			
Mark	No.	Size	Length.
b	24	1 1/8"□	21'-0"
b1	104	1/2"□	10'-0"
C	72	1 1/4"□	15'-3"
C1	246	3/8"φ	7'-0"
d	100	3/4"φ	4'-0"
Af	100	1 1/8"□	18'-3"
Af1	21	3/4"φ	26'-6"
d1	7	3/4"φ	7'-0"
Aw1	112	1 1/8"□	14'-0"
Aw2	130	1"□	9'-9"
Aw3	38	1/2"□	26'-6"
Ts	67	7/8"φ	15'-9"
Ts1	68	7/8"φ	14'-6"
Tsa	18	3/4"φ	24'-9"
Tsh	3	1/2"φ	24'-9"
Tsh1	3	1/2"φ	26'-9"
Tsh2	3	1/2"φ	11'-9"
Tsh3	3	1/2"φ	11'-9"
Tsh4	3	1/2"φ	26'-9"
Tsv.	67	1/2"φ	5'-6"
Tsv1	25	1/2"φ	7'-3"
d2	4	3/4"φ	9'-3"

Detail of Bent Bars.

Note: Footings designed for a toe pressure of 3.7 tons per Sq. ft.

Note:
All concrete to be Portland Cement Class "C".
Water proof top and back of abutments and wing walls with Ironite or Euco, iron oxide waterproofing.
No construction joints will be allowed excepts where noted on plans. Construction joints must be properly cleaned and keyed so as to secure good bond at the joints.
All dimensions relative to reinforcing steel are to centers of bars.
All exposed surfaces to receive Class "1" surface finish, excepts, curved ceiling of walkway which is to receive Class "2" surface finish.
See dwg. #4112 for detail of rustications. Bridge seat shall be floated and troweled to a true level grade or left one-quater inch high and bush hammered to an exact level.
For sidewalk finish see specifications.
All exposed corners to be chamfered 1".

Southern Railway Company
Lines East
Detail Plan of Reinforced Concrete Abutment "A"
for Underpass at Roxboro Street,
DURHAM, N.C. **M.P. H-55.24**
Scales: 3/16", 3/8", 1/2" = 1'-0" January 7, 1929
DWG. No. 4113
Office of Chief Engineer M.W.+S., Charlotte, N.C.

Designed, Drawn, Traced, by - R.A.M. Deal -- Date: Jan. 7, 1929.
Checked by --- Date: