Retrofit Techniques for Floating Slab Track

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The floating slab has been the primary method for mitigation of underground noise and vibrations in the Washington Metropolitan Area Transit Authority's (WMATA's) Metrorail system. Because of one type of defective polyurethane isolator pad supporting the floating slabs, about 18,800 track ft of floating slabs have settled unevenly, causing operation and maintenance problems. As an emergency measure, WMATA's maintenance forces raised the rails to the proper elevations by inserting shims under the rail fasteners on the floating slabs. There are about 80,000 ft (15 mi) of floating slabs in the WMATA operating system. About 22,400 ft (4.2 mi) are resting on this type of polyurethane pads, and 18,800 ft (3.5 mi) require new pads. Replacing pads under a floating slab segment 60 ton, 60 ft long, under restricted working conditions, presents a real challenge. The working hours are limited to nonrevenue hours between midnight and 5:00 a.m. Many techniques of repair have been developed and tried with the assistance of De Leuw, Cather and Company, WMATA's General Engineering Consultant. Two techniques have been successfully tried and are being used to lift the floating slabs for pad replacement. The retrofit has been performed by a Design Build team consisting of the Office of Engineering and Architecture and the maintenance forces from the Office of Track and Structure. For the circular tunnel sections, the technique is called window cutting with jacks and beams. For the box sections and passenger stations, the technique is called window cutting with jacks and stools. For the crossover and turnout areas, the technique has not been developed. It will probably be a variation of the window cutting with jacks and stools technique. As of December 1994, about 5,241 ft (1 mi) of floating slabs have been retrofitted by these two techniques with new natural rubber pads. To complete the retrofit, track alignment survey, noise and vibration measurements, and structural restoration are being performed after the pad replacement. The work is continuing wherever the track-right is available and may take the rest of the century to complete.

Floating slabs have been designed and installed in Washington Metrorail tunnels to reduce ground-borne vibration and noise transmitted to adjacent buildings. The concrete floating slabs rest on fiberglass, natural rubber, or polyurethane pads. Each pad is 6 in. in diameter or 6 in. square by 3 in. thick, spaced 2 ft on center. These pads serve as cushions to isolate structurally the floating slabs from the adjacent invert slabs (Figure 1).

There are two basic types of floating slabs, as shown on Figure 2. Type 1 is used in special trackwork (crossovers and turnouts) areas; Type 2, with two variations, is used in tunnel sections. The box section version of Type 2 has the contact rail sharing the same support with the running rail on the floating slab. The circular section version of Type 2 has the contact rail sitting on the adjacent invert slab.

The polyurethane pads furnished by one supplier were compressed unevenly (from 3 in. thick to as thin as ¼ in.) causing the slab to settle. The defective pads looked like squashed donuts. The worst ones disintegrated into piles of mud. Because the slab supports the track, this settling condition causes operation and maintenance problems including differential settlement, cross-level changes, contact rail height misalignment, uneven surfacing, corrugation, rail fastener breakdown, and train speed restriction. As an emergency measure, WMATA's maintenance forces from the Office of Rail Track and Structures raised the rails to the proper elevations by inserting shims under the rail fasteners on top of floating slabs (Figure 3).

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RETROFIT PROGRAM

There are 80,000 ft (15 mi) of floating slabs in the WMATA operating system. About 22,400 ft (4.2 mi) are resting on this type of polyurethane pads, and 18,800 ft (3.5 mi) require new pads.

Investigation Phase

Replacing pads under a 60-ton, 60-ft long floating slab segment under restricted working conditions is a challenge. Working hours are limited to nonrevenue hours between midnight and 5:00 a.m. Solutions had to be found before the replacement work could begin. De Leuw, Cather and Company (DCCO), WMATA's general engineering consultant, helped develop an investigation plan. It included

1. Problem Identification:
   –Review available criteria, specifications, shop drawings and test reports.
   –Conduct field survey to determine existing settlement and monitor future settlement.
   –Take noise and vibration measurements to determine whether the floating slabs are functioning as designed.
   –Test the defective pads to determine causes of the failure.
2. Analysis:
   –Develop criteria and specifications for procuring replacement pads.
   –Develop schemes for replacing the defective pads.
   –Develop procedures for demonstrations of the retrofit schemes.
3. Action Plan:
   –Perform equipment design and cost analysis.
   –Schedule on-site demonstrations of feasible retrofit schemes.
   –Evaluate and determine which schemes work implementation.

On the basis of a laboratory testing report prepared by the University of Akron, the defective pads were cured by the wrong method and the material compound consisted of polyester, which is much less resistant to hydrolysis than the polyether type of polyurethane for this application.

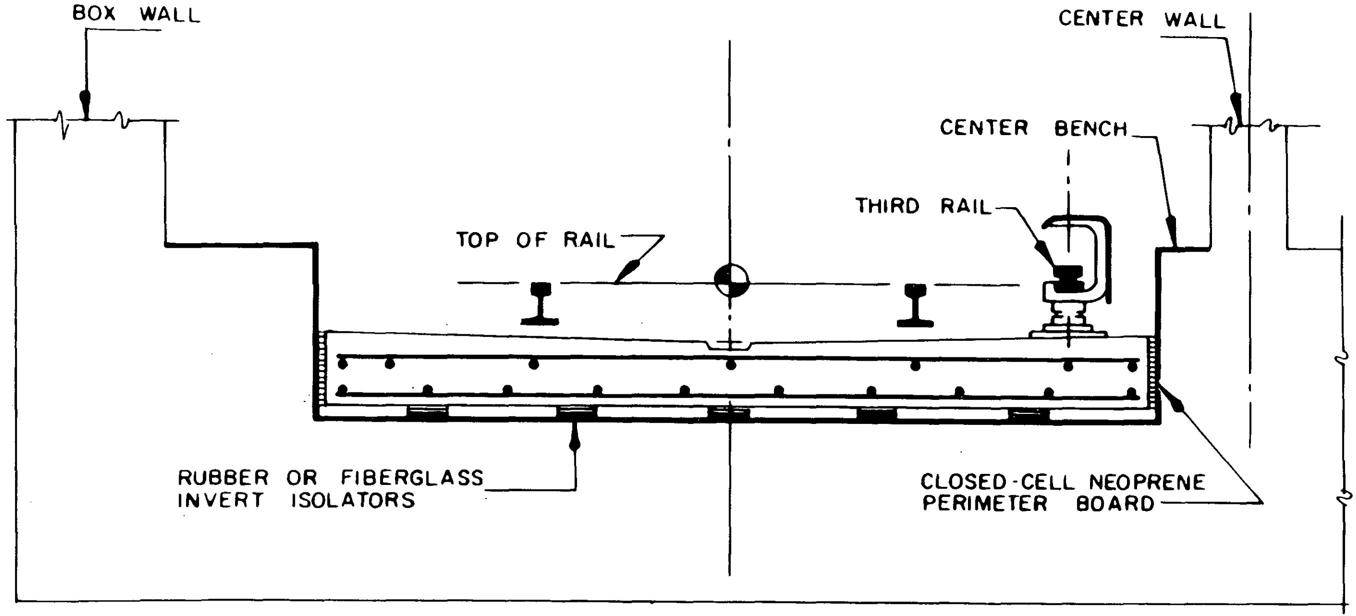


FIGURE 1 Typical floating slab section in subway box.

For the replacement pad design, 12-in. diameter by 3-in. thick natural rubber pads spaced 30 in. on center under the centerline of rail will be used for the Type 2 floating slabs, and 7½-in. diameter by 3-in. thick natural rubber pads bonded with steel plates on top and bottom, spaced 24 in. apart will be used for the Type 1 floating slabs. Natural rubber was chosen because it has better physical properties and creep characteristics (Figure 4).

Noise and vibration measurements conducted by Wilson, Ihrig & Associates, Inc., Acoustical Consultant, indicated the performance of the floating slab varied from one problem area to the next. With this information, it was determined how much of the attenuation should be restored in each area (Figure 5).

Implementation Phase

Replacement of the defective pads had been studied extensively. Many techniques were developed jointly by WMATA and DCCO, and three are workable under the restricted operating conditions. They are discussed in the following sections.

Window Cutting With Jacks And Beams

Figure 6 shows the general concept of this technique. It applies to the circular tunnel section with 7 ft 6 in.-wide floating slabs. The

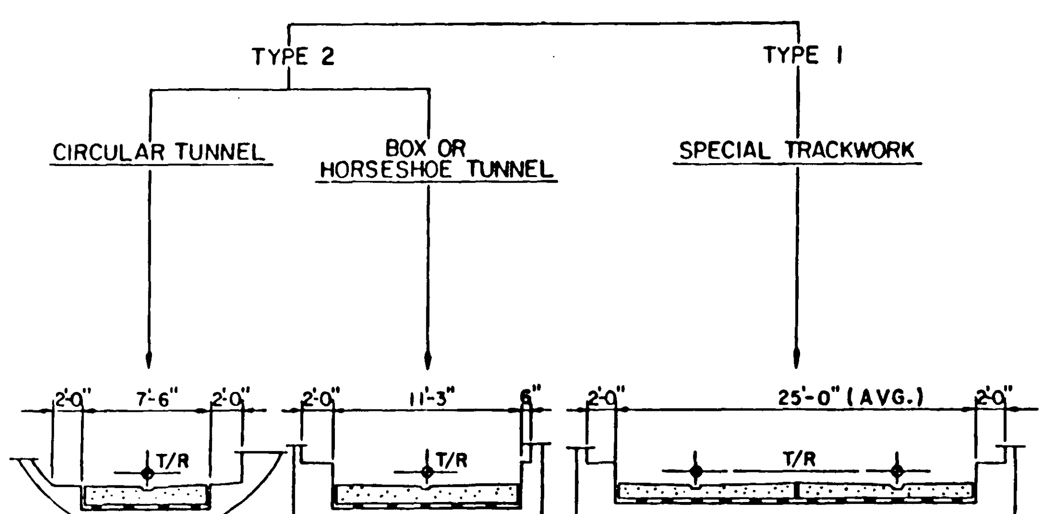


FIGURE 2 WMATA existing floating slab configurations.

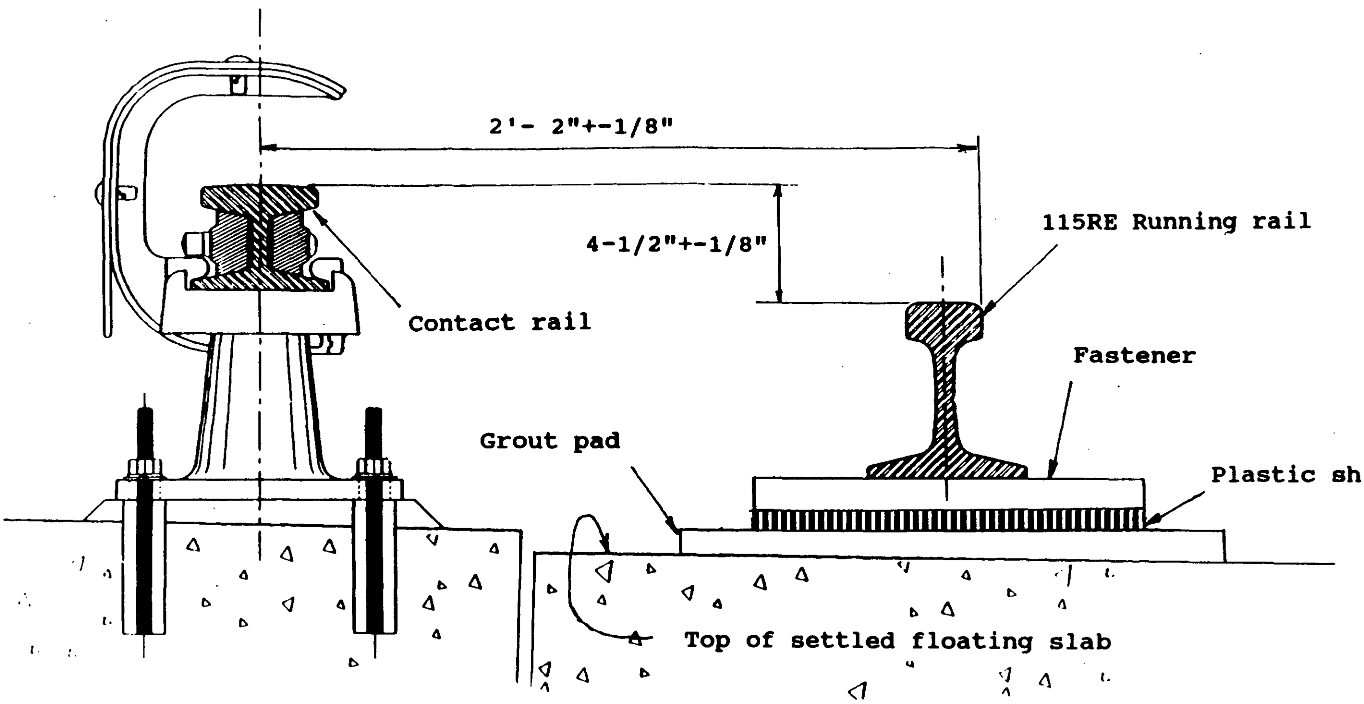


FIGURE 3 Settled floating slab with shim.

procedure is to core 16-in. diameter holes, 4 ft apart, through the 14-in. thick concrete slab, including the ⅛-in. metal pan used to support the slab during construction, along the centerline of the track. These openings are used for access to remove the defective pads and to install the new natural rubber pads. This coring can be done in advance without disturbing the existing track. Each hole takes about 50 min to make. Figure 7 shows the sections before and after the lifting operation. The jacking unit consists of a steel beam, two jacks with four hangers, and four rail fastener clamps. A synchronized jacking system (control box) is used to control the lifting operation. The steps are

1. Preparatory Work:
   - –Perform structural analysis for the lifting system.
   - –Procure 50-ton hydraulic jacks, steel beams, hangers, straps, synchronized control box, and other hardware.
   - –Procure new pads.
   - –Core 16-in. diameter holes 4 ft apart along centerline of track.
   - –Coordinate with Operations Central Control for work schedule.
   - –Transport material and equipment, in advance, to the end of the station platform or fan vent shaft adit near the job site.
2. Retrofit Operation:
   - –Turn off electric power on contact rail.
   - –Secure work area.
   - –Set up the lifting equipment.
   - –Loosen the rail clips about 50 ft beyond each end of the floating slab segment to be lifted.
   - –Lift the floating slab 4 to 6 in.
   - –Insert 9-in. long square steel tube between the 16-in. holes to provide additional slab support in case of jack failure.
   - –Remove defective pads from under the slab along the centerline of each rail.
   - –Place new pads at 30-in. spacing under the centerline of each rail beneath the slab.
   - –Lower the floating slab on the new pads.
   - –Adjust both running rails and contact rail.
   - –Provide rail transition tapering on each end of raised floating slab.

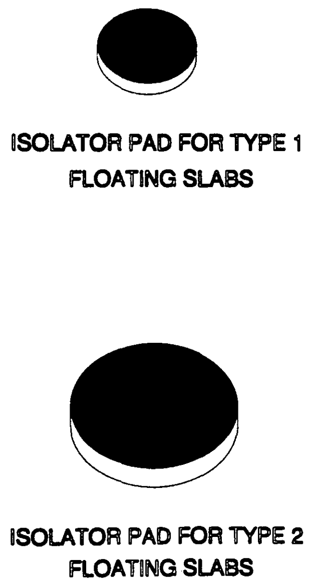


FIGURE 4 Replacement pads.

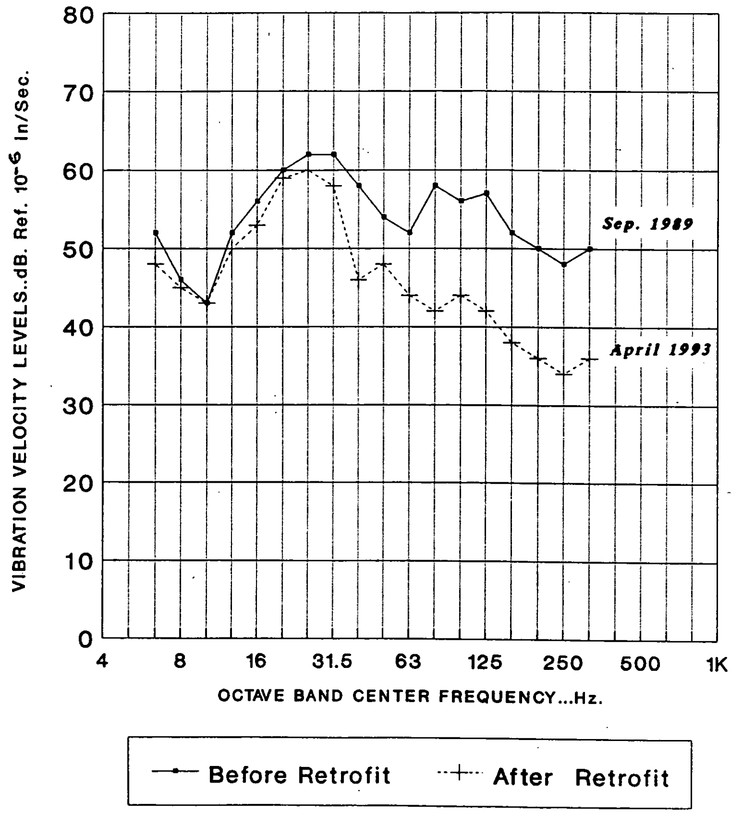


FIGURE 5 Vibration measurements before and after retrofit (at Capitol South Station on tunnel safety walk 100 ft from platform).

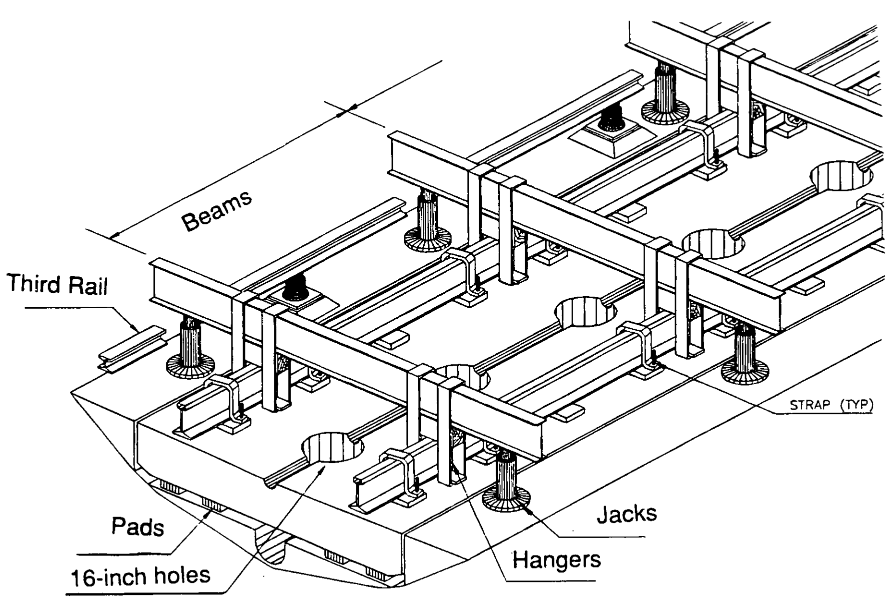


FIGURE 6 Details of jacks and beams technique.

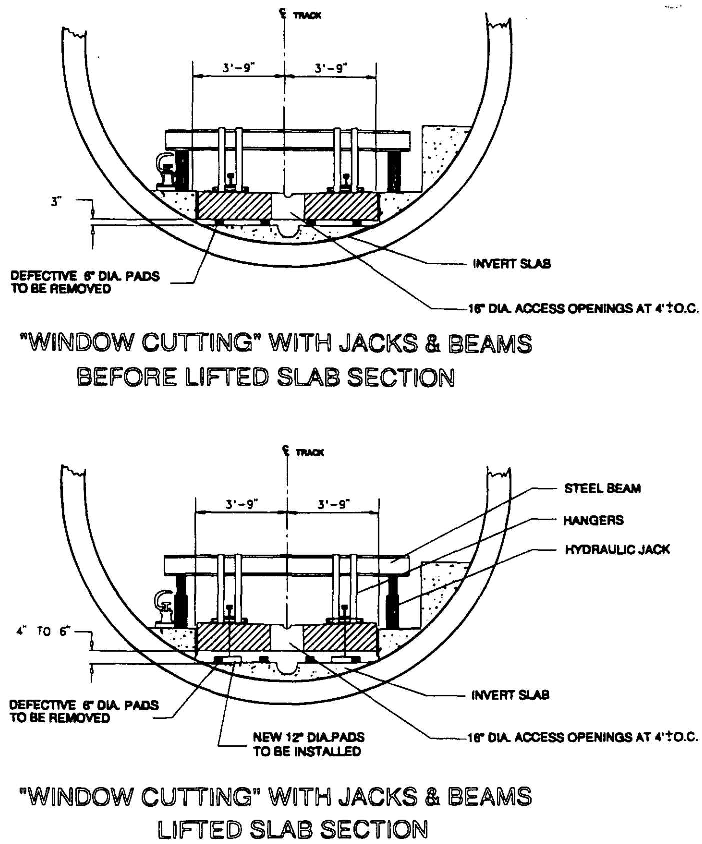


FIGURE 7 Sections before and after retrofit.

–Tighten rail clips.

–Replace concrete cores in the 16-in. holes with temporary 3-in. thick wooden block support.

–Run test train with speed restriction.

3. Restoration Work:

–Conduct field survey to determine as-retrofitted track conditions.

–Adjust rail profile and alignment.

–Conduct noise and vibration measurements to determine how much the attenuation has been restored.

–Remove concrete cores from the 16-in. holes and cover the holes with gray iron grates.

–Inspect floating slab and repair as required.

–Replace perimeter board at each side of floating slab.

Window Cutting With Jacks And Stools

Figure 8 shows the general concept of this technique. It applies to the slabs 11 ft 3 in. wide in the box sections, stations, and fan vent shaft sections where there is no room for jacks and beams. The procedure is the same as the window cutting with jacks and beams technique except for the lifting equipment. In addition, 5-in. diameter holes spaced 9 ft apart along the field side of the rails are cored while the 16-in. diameter holes are being cored. These 5-in. diameter holes permit the specially designed jacking unit to sit on the stand with stool-like equipment to lift the slab against the invert slab below. The stools are anchored to the top of slab around the 5-in. holes with four ⅞-in. anchor bolts. Figure 9 illustrates the layout of the system, and Figure 10 shows the sections before and after the lifting operation.

Variation of Jacks And Stools

This technique applies to special trackwork area. It is a variation of the jacks and stools technique and is still in the development stage. Briefly, the 16-in. diameter access holes and the 5-in. jacking stool holes are strategically located on the variable shape of floating slabs between the rails for the lifting operation. A demonstration of this technique is scheduled in fall 1995.

Progress Status

As of December 1994, about 5,241 linear ft of floating slabs were lifted for pad replacement. Because of restricted working hours, the estimated annual production rate is about 2,400 ft of floating slabs. In early retrofit operation, the time available to lift the floating slabs was limited to weekend after-midnight hours only. The improved skills and equipment, with single-track operation allowed at some locations, make it possible to retrofit on week nights. In fact, week

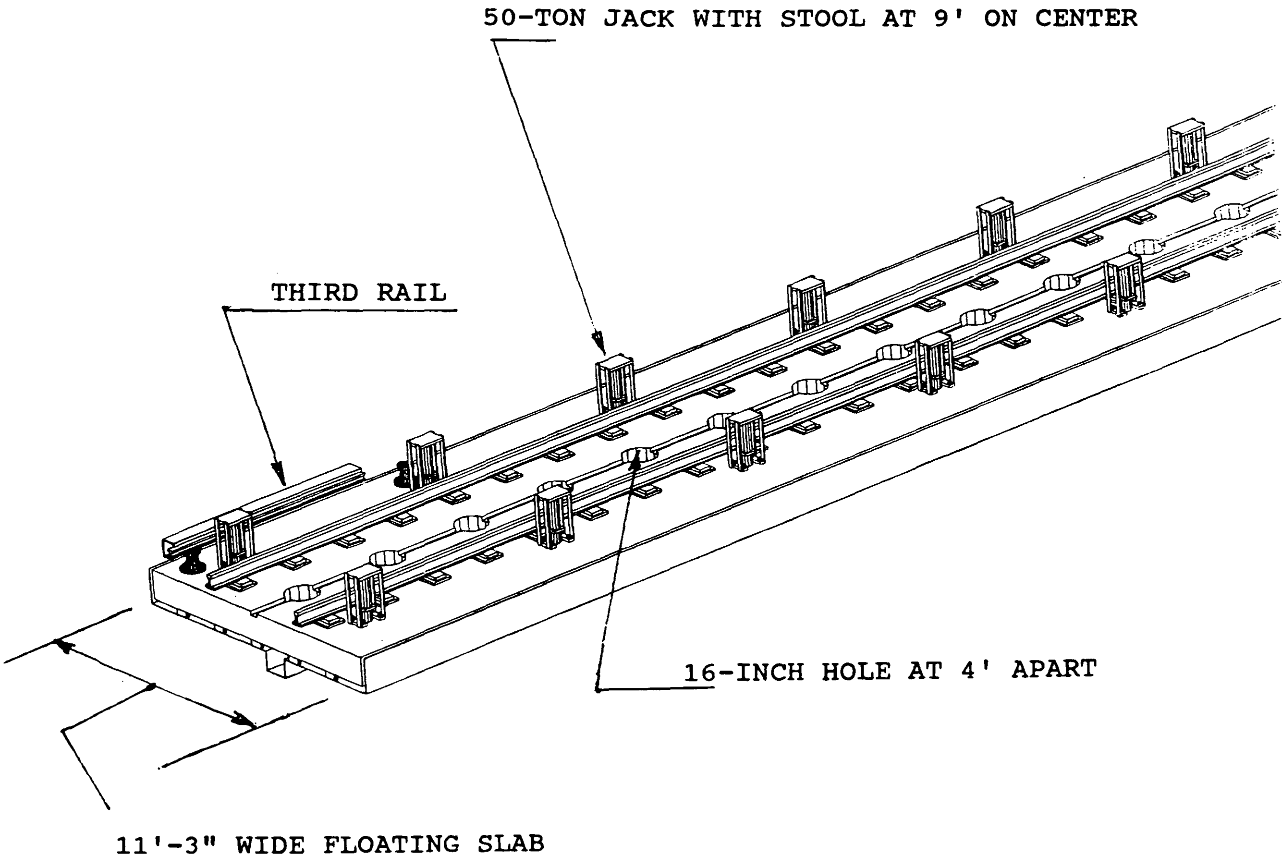


FIGURE 8 Window cutting technique with jacks and stools.

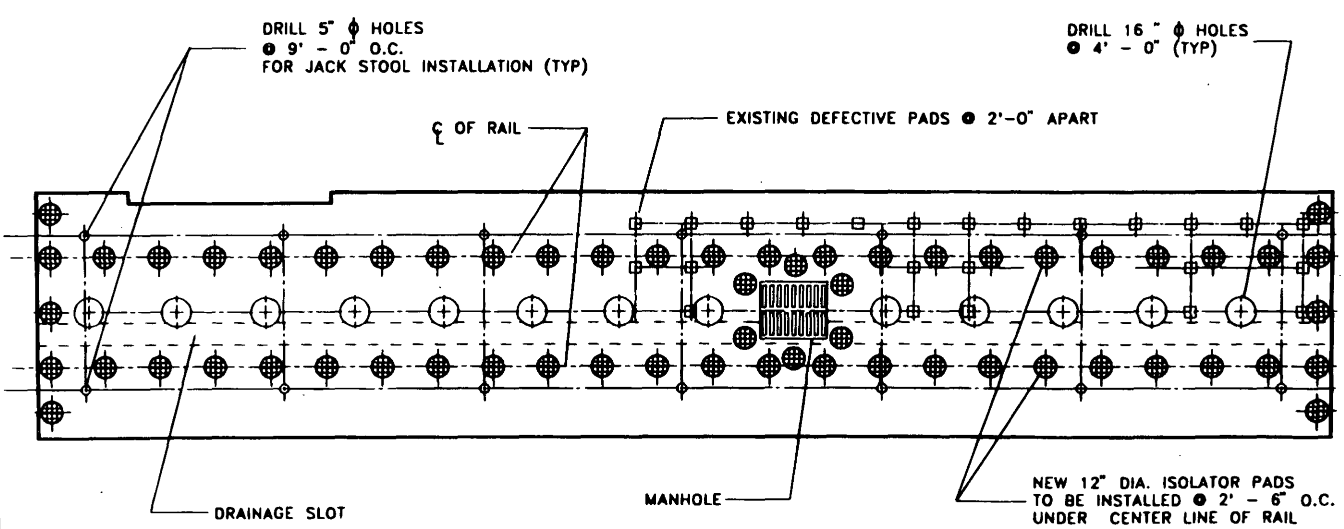
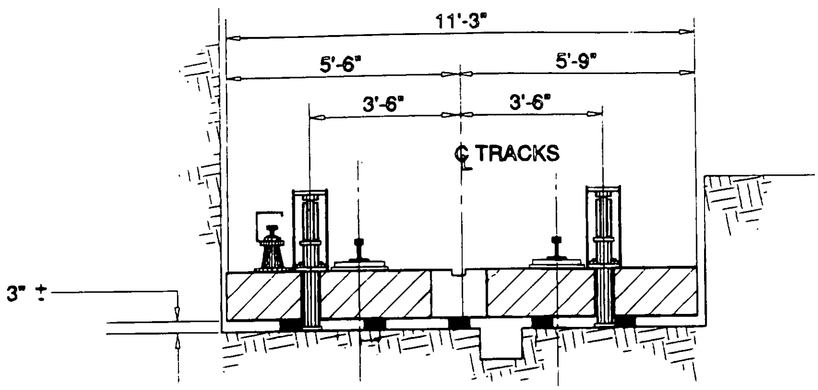
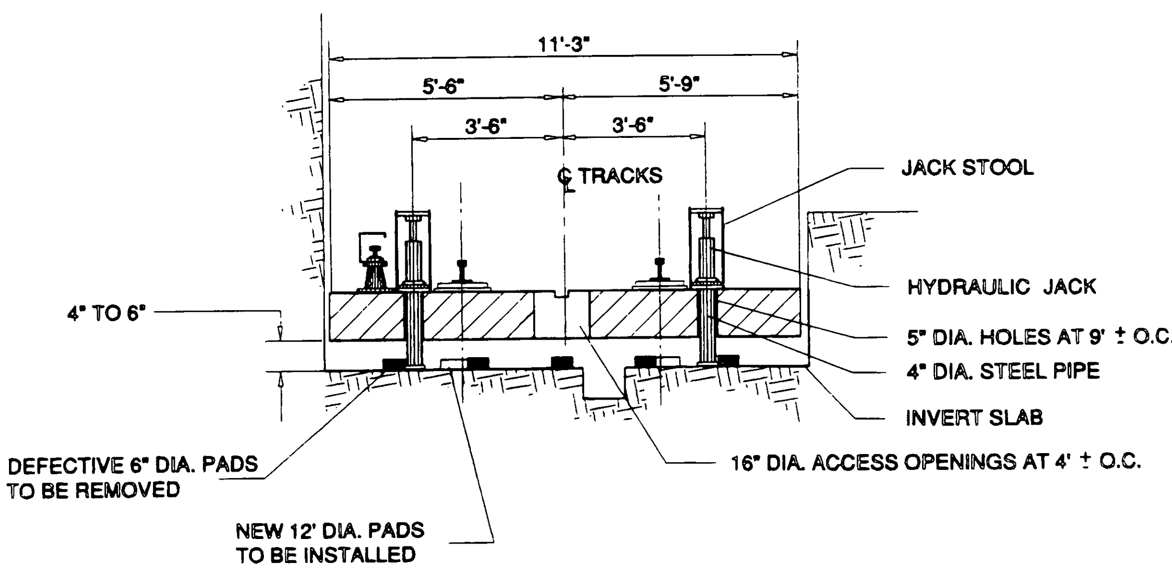


FIGURE 9 Typical layout of jacks and stools technique.



"WINDOW CUTTING" WITH JACK & STOOL
SLAB SECTION BEFORE LIFTING



"WINDOW CUTTING" WITH JACKS & STOOLS
LIFTED SLAB SECTION

FIGURE 10 Sections showing before and after retrofit.

TABLE 1 Floating Slab Retrofit Status

No	Contract Number	Section	Stationing	Length Feet	Slab Type	Track	Retrofit Method	Task Order	Date of Completion For				Tunnel - Trackwork Configuration
									Pad Repl.	Survey	Noise	Structure	
1	1A0062	A-6b	167+00 to 172+63	563	2	IB	B						Station
			167+00 to 172+63	563	2	OB	B						Station
			175+00 to 184+00	900	2	IB	A						Tunnel(circular)
			175+00 to 184+00	900	2	OB	A						Tunnel(circular)
			193+90 to 197+31	341	1	IB	C						#8 Double Crossover
			193+90 to 197+31	341	1	OB	C						#8 Double Crossover
			197+31 to 202+00	469	2	IB	B						Station
			197+31 to 202+00	469	2	OB	B						Station
			217+89 to 221+00	311	2	IB	A	4	05/16/93				Tunnel(circular)
			217+89 to 221+00	311	2	OB	A	1	11/07/92	06/14/93			Tunnel (circular)
2	1A0092	A-9b	305+25 to 308+80	355	1	IB	C						#8 Double Crossover
			305+25 to 308+80	355	1	OB	C						#8 Double Crossover
3	1C0031(a	C-4	86+80 to 88+30	150	2	OB	A						Tunnel(circular)
4	1C0051	C-5	145+37 to 147+15	178	1	IB	C						#15 Turnout
			145+04 to 146+82	178	1	OB	C						#15 Turbout
5	1C0062	C-6b	256+15 to 257+93	178	1	IB	C						#15 Turnout
			256+14 to 257+92	178	1	OB	C						#15 Turbout
			264+74 to 266+52	178	1	IB	C						#15 Turnout
			264+74 to 266+52	178	1	OB	C						#15 Turnout
6	1C0071	C-7	287+80 to 290+32	252	1	IB	C						#8 Double Crossover
			287+80 to 290+32	252	1	OB	C						#8 Double Crossover
7	1D0011	D-1	9+50 to 11+50	200	2	OB	A						Tunnel (circular)
		C-1	2+70 to 5+00	230	2	OB	A						Tunnel (circular)
		C-1	3+35 to 5+50	215	2	IB	A						Tunnel (circular)
8	1D0031(b	F-1	42+69 to 44+86	217	1	IB	C						#8 Double Crossover
			42+69 to 44+86	217	1	OB	C						#8 Double Crossover
			51+66 to 53+44	178	1	IB	C						#15 Turnout
			51+66 to 53+44	178	1	OB	C						#15 Turnout
9	1D0041	D-4a	100+02 to 103+20	318	2	IB	A	2	12/12/92	02/28/93	04/20/93		Tunnel (circular)
			100+02 to 103+20	318	2	OB	A	3	05/03/93	05/14/93			Tunnel (circular)
			105+80 to 106+97	117	2	OB	A	15	12/08/94				Tunnel (circular)
			106+97 to 107+55	58	2	IB	B	7	03/05/94				Vent Shaft (11'-3" slab)
			106+97 to 107+55	58	2	OB	B	18	01/28/95				Vent Shaft (11'-3" slab)
10	1D0042	D-4b	83+53 to 87+43	391	1	IB	C						#8 Double Crossover
			83+53 to 87+43	391	1	OB	C						#8 Double Crossover
11	1D0071	D-7	167+36 to 167+90	54	2	IB	B	14	11/21/94				Vent Shaft (11'-3" slab)
			167+36 to 167+90	54	2	OB	B	11	10/06/94				Vent Shaft (11'-3" slab)
			167+90 to 173+90	600	2	IB	B	10	08/02/94				Station
			167+90 to 173+90	600	2	OB	B	12	11/02/94				Station
			173+90 to 174+82	92	2	IB	B	9	05/24/94				Vent Shaft (11'-3" slab)
			173+90 to 174+82	92	2	OB	B	13	11/08/94				Vent Shaft (11'-3" slab)
12	1D0081(c)	D-8	174+82 to 175+42	60	2	IB	B	14	11/21/94				Vent Shaft (11'-3" slab)
			175+42 to 185+90	1048	2	IB	A	8	04/22/94				Tunnel (circular)
			174+82 to 175+42	60	2	OB	B	11	10/06/94				Vent Shaft (11'-3" slab)
			174+52 to 185+20	978	2	OB	A	6	02/27/94				Tunnel (circular)
13	1F0021	F-2a	59+60 to 62+30	270	2	IB	A	17	01/08/95				Tunnel (circular)
			59+70 to 62+10	240	2	OB	A						Tunnel (circular)
			66+00 to 67+70	170	2	IB	A	5	12/12/93				Tunnel (circular)
			65+80 to 67+80	200	2	OB	A						Tunnel (circular)
			70+80 to 72+70	190	2	IB	A	16	01/03/95				Tunnel (circular)
			71+20 to 72+30	110	2	OB	A						Tunnel (circular)
			84+00 to 86+18	218	2	OB	A						Tunnel (circular)
			86+18 to 86+60	42	2	OB	B						Vent Shaft (11'-3"slab)
		L-1	59+60 to 62+30	270	2	IB	A	[illegible]					Tunnel (circular)
			66+80 to 69+80	300	2	IB	A	[illegible]					Tunnel (circular)

(continued on next page)

TABLE 1 *(continued)*

14	1F0022	F-2b	86+60 to 87+42	82	2	OB	B						Vent Shaft (11'-3" slab)
			93+40 to 94+00	60	2	OB	B						Vent Shaft (11'-3" slab)
15	1G0031	G-3	427+31 to 432+81	550	2	IB	A						Tunnel (circular)
			427+27 to 432+77	550	2	OB	A						Tunnel (circular)
			437+00 to 442+90	590	2	IB	A						Tunnel (circular)
			436+91 to 443+56	665	2	OB	A						Tunnel (circualr)
			445+77 to 448+77	300	2	IB	A						Tunnel (circular)
			445+53 to 449+19	366	2	OB	A						Tunnal (circular)
16	1A0141	A-14	593+62 to 601+48	786	2	IB	B						Box Tunnel (11'-3" slab)
			593+62 to 601+48	786	2	OB	B						Box Tunnel (11'-3" slab)
17	1A0101	A-10a	329+00 to 336+00	700	2	IB	A						Tunnel (circular)
			329+00 to 336+00	700	2	OB	A						Tunnel (circular)
18	1A0131	A-13	569+25 to 569+75	50	2	OB	B						Box tunnel (11'-3" slab)
			569+75 to 571+75	200	1	OB	C						#8 Turnout
			571+75 to 573+25	150	2	OB	C						Box Tunnel (13'-3" slab)
			569+25 to 569+75	50	2	IB	B						Box Tunnel (11'-3" slab)
			569+75 to 571+75	200	1	IB	C						#8 Turnout
			571+75 to 573+25	150	2	IB	C						Box Tunnel (13'-3" slab)
			571+75 to 572+25	50	1	STOR	C						Central Storage Track (17'-0")
19	1K0021	K-2	205+68 to 210+18	450	2	IB	B						Box Tunnel (11'-3")
			205+68 to 210+18	450	2	OB	B						Box Tunnel (11'-3")
			220+48 to 223+09	261	1	IB	C						#8 Double Crossover
			220+48 to 223+09	261	1	OB	C						#8 Double Crossover

NOTES:

1. All defective isolator pads are made of polyurethane except for Sections C-4 and D-8 which are made of fiberglass
2. (a) Contractor for 1C0031 installed the floating slabs in Section C-4 No slab settlement was reported on 01/30/95. Not included in length count.
   (b) Contractor for 1D0041 installed the floating slabs in Section F-1.
   (c) Fiberglass pads by Transit Track, 60 Ft. (IB & OB) were polyurethane pads.
3. Method A: Applicable to circular tunnel sections, window cutting with jacks and beams. 10,209 feet (polyurethane). 2,026 feet (fiberglass).
   Method B: Applicable to wider slabs in stations and box sections, window cutting with jacks and stools. 6,548 feet (polyurethane).
   Method C: Applicable to special trackwork sections. 5,808 feet (polyurethane).
4. Length with defective polyurethane pads is 22,565 feet and with fiberglass pads is 2,026 feet.

nights have become the norm with the weekend as an option. Table 1 shows the typical progress status of this endeavor.

ACKNOWLEDGMENT

Tony Adams, Superintendent of Special Projects of WMATA's Office of Rail Track and Structure, deserves special recognition for his valuable contribution in solving this difficult maintenance problem. Acknowledgement is given to Mohammad Irshad and his staff of De Leuw, Cather and Company for their engineering support, Special appreciation is also expressed to Don Painter, Office of Rail Track and Structures, Ik Pyo Hong, and Ado Valge, Office of Engineering and Architecture, WMATA, for providing constructive guidance and Fady P. Bassily, WMATA, for continuing support.

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