

TCRP

REPORT 71

TRANSIT
COOPERATIVE
RESEARCH
PROGRAM

Track-Related Research

Volume 6:

*Direct-Fixation Track Design
Specifications, Research,
and Related Material*

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Specifications, Research,
and Related Material***

***Part A: Direct-Fixation Track Design
and Example Specifications***

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TRANSIT COOPERATIVE RESEARCH PROGRAM

The nation's growth and the need to meet mobility, environmental, and energy objectives place demands on public transit systems. Current systems, some of which are old and in need of upgrading, must expand service area, increase service frequency, and improve efficiency to serve these demands. Research is necessary to solve operating problems, to adapt appropriate new technologies from other industries, and to introduce innovations into the transit industry. The Transit Cooperative Research Program (TCRP) serves as one of the principal means by which the transit industry can develop innovative near-term solutions to meet demands placed on it.

The need for TCRP was originally identified in *TRB Special Report 213—Research for Public Transit: New Directions*, published in 1987 and based on a study sponsored by the Urban Mass Transportation Administration—now the Federal Transit Administration (FTA). A report by the American Public Transportation Association (APTA), *Transportation 2000*, also recognized the need for local, problem-solving research. TCRP, modeled after the longstanding and successful National Cooperative Highway Research Program, undertakes research and other technical activities in response to the needs of transit service providers. The scope of TCRP includes a variety of transit research fields including planning, service configuration, equipment, facilities, operations, human resources, maintenance, policy, and administrative practices.

TCRP was established under FTA sponsorship in July 1992. Proposed by the U.S. Department of Transportation, TCRP was authorized as part of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). On May 13, 1992, a memorandum agreement outlining TCRP operating procedures was executed by the three cooperating organizations: FTA, The National Academies, acting through the Transportation Research Board (TRB); and the Transit Development Corporation, Inc. (TDC), a nonprofit educational and research organization established by APTA. TDC is responsible for forming the independent governing board, designated as the TCRP Oversight and Project Selection (TOPS) Committee.

Research problem statements for TCRP are solicited periodically but may be submitted to TRB by anyone at any time. It is the responsibility of the TOPS Committee to formulate the research program by identifying the highest priority projects. As part of the evaluation, the TOPS Committee defines funding levels and expected products.

Once selected, each project is assigned to an expert panel, appointed by the Transportation Research Board. The panels prepare project statements (requests for proposals), select contractors, and provide technical guidance and counsel throughout the life of the project. The process for developing research problem statements and selecting research agencies has been used by TRB in managing cooperative research programs since 1962. As in other TRB activities, TCRP project panels serve voluntarily without compensation.

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The TCRP provides a forum where transit agencies can cooperatively address common operational problems. The TCRP results support and complement other ongoing transit research and training programs.

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The members of the technical advisory panel selected to monitor this project and to review this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project. The opinions and conclusions expressed or implied are those of the research agency that performed the research, and while they have been accepted as appropriate by the technical panel, they are not necessarily those of the Transportation Research Board, the National Research Council, the Transit Development Corporation, or the Federal Transit Administration of the U.S. Department of Transportation.

Each report is reviewed and accepted for publication by the technical panel according to procedures established and monitored by the Transportation Research Board Executive Committee and the Governing Board of the National Research Council.

To save time and money in disseminating the research findings, the report is essentially the original text as submitted by the research agency. This report has not been edited by TRB.

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AUTHOR ACKNOWLEDGMENTS FOR PART B

The research reported herein was originally performed by Battelle under earlier TCRP funding (TCRP Project D-5, "Performance of Direct Fixation Track Structure"). Mr. James M. Tuten III, P.E., is this Report's primary author and was the principal investigator and general supervisor of the original work. TransTech Management and L. E. Daniels Transportation Engineering participated in the original work as subconsultants to Battelle.

Special appreciation is extended to the transit agencies shown in Part B, Appendix C, for their help identifying the needs of the tran-

sit industry. Similarly we wish to acknowledge the contributions from the large number of vendors that were so forthcoming with fasteners and components for laboratory testing, along with their insights. We also wish to acknowledge the Kowloon Canton Railroad Corporation for allowing us to release the large amount of data obtained during a related research effort. Finally we wish to acknowledge the use of results obtained during a related project conducted for the Frankford Elevated Reconstruction Project (FERP).

FOREWORD

*By Christopher W. Jenks
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This report should be of interest to engineers involved in the design, construction, and maintenance of direct-fixation track systems, a subset of non-ballasted track systems. The two-part report provides guidance on the design and construction of direct-fixation track systems. Part A includes sections describing track-design principles and material-evaluation methods for direct-fixation fasteners and track, as well as example specifications and commentary for direct-fixation fasteners, direct-fixation fastener qualification and production tests, direct-fixation track construction, and materials used in direct-fixation applications. The purpose of the commentary provided with the example specifications is to explain the basis for specification stipulations, the relevance of stipulations in various applications, and key issues and trade-offs that must be made in developing specifications for the design and construction of direct-fixation track systems. Part B of the report provides data, evaluations, field reviews, and analyses of direct-fixation fasteners from a variety of sources to understand their characteristics and proper application more fully.

Direct-fixation track is the earliest form of track without ballast, originating in the 1960s on the New York City subway system. It has won acceptance as a cost-effective measure in reducing tunnel and aerial structure construction costs. It has been promoted further for reducing track maintenance, stray current, and ground-borne vibrations. As a result of these benefits, an array of direct-fixation products have emerged. When faced with various claims for performance characteristics among competing products, transit agencies need objective information regarding direct-fixation characteristics to allow for independent judgment of claims and recommendations to assist in the design and construction of direct-fixation track systems.

Under TCRP Project D-7, Task 11, Laurence E. Daniels, Railroad Consulting Engineer, in collaboration with James Tuten and William Moorhead, was asked to develop guidance for transit systems regarding the design and construction of direct-fixation track systems, building upon work previously completed under TCRP Project D-5, "Performance of Direct-Fixation Track Structure." This guidance takes the form of examples of design and construction specifications and related background material provided on *CRP-CD-61*.

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CRP-CD-61

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TRACK-RELATED RESEARCH

VOLUME 6: DIRECT-FIXATION TRACK DESIGN SPECIFICATIONS, RESEARCH, AND RELATED MATERIAL

OVERVIEW This report documents direct-fixation track design principles and specification practices in Part A and direct-fixation fastener research in Part B.

Direct-fixation track is the earliest form of track without ballast, originating with a fastener in the 1960s on the New York subway system. The New York fastener was a plate on a pad, both of which were anchored directly to supporting concrete. This track form received broader attention in the early 1970s when the Long Island Railroad and the Bay Area Rapid Transit System (BART) implemented a modern version to reduce dead load on their aerial structures. These systems implemented a fastener, the first bonded metal-rubber “sandwich,” which is also bolted to a concrete deck or plinth. That original design criterion from BART has evolved but remains central in most of the “conventional” direct-fixation specifications to 2004.

Direct-fixation track has won acceptance as a cost-effective measure in reducing tunnel and aerial structure construction costs. It has been promoted further for reducing track maintenance, stray current, and ground-borne vibrations. The aggregation of attributes has spawned an array of direct-fixation fastener products¹ and parallel concepts, now generally termed “ballastless track.”

Ballastless track now includes embedded block track and embedded rail track as parallel categories to direct-fixation track. Subcategories of embedded block track are “resilient tie,”² embedded concrete tie, and embedded wood tie³; all are cast into support concrete. Embedded rail track is generally street track where the surrounding surface is at the top of rail with only the top of rail and flangeway visible. Embedded rail

¹ Direct-fixation fasteners are all “plate-type” fasteners, meaning the fastener units are uniformly supported in the same sense as the common tie plate. Direct-fixation fastener designers attempt to distinguish their products by creating distinct direct-fixation category names. Among the plate-type direct-fixation fasteners are “constrained elastomer” or “framed fasteners” (elastomer is constrained within a frame); sandwich fasteners (top plate, with or without a bottom plate, with elastomer under the top plate); bonded fasteners (either sandwich or framed fastener designs with the elastomer vulcanized to the steel plates or frames); and non-bonded (sandwiched or framed fasteners without elastomer vulcanization).

² The resilient tie system is a concrete block set on an engineered pad, with the block’s lower portion and pad encased in an elastomer “boot” that is embedded in support concrete up to the top of the boot. The resilient tie system uses one block on each rail located directly across from each other. The resilient tie concept was developed in Europe in the 1960s, originally on the Swiss Federal Railway system, then on other properties. It was introduced into North America in the 1970s.

³ Embedded concrete or embedded wood tie track types may be single blocks under each rail (sometimes termed “dual block” ties) or may be a single monoblock tie supporting both rails.

track may be designed with direct-fixation fasteners, with conventional cross-ties and fasteners, or without any ties or fasteners.

The scope of this work is focused on direct-fixation track and fasteners, the subcategory of ballastless track that implies “plate-type” fasteners. Embedded block track is sufficiently close in many aspects that the report’s information is generally relevant. The practices and results offered in this report may not be applicable to embedded rail track depending on whether it uses direct-fixation fasteners and whether embedment material is in contact with the rail.

The reason for this report is to address several industry concerns.

When faced with various claims for performance characteristics among competing ballastless track products and a history of expensive implementations based upon the recommendations of specialist consultants, transit agencies expressed their desire for objective information on direct-fixation characteristics to allow independent judgment of supplier and consultant claims and recommendations.

Suppliers question the expense and complexity of qualification testing. Transit agencies are questioning both the qualification and construction specifications based on experiences with subtle conflicts that have created awkward results and experiences in which key stipulations were missing, such as minimum fastener bearing contact on the support. Additionally, successful completion of the qualification tests has not proven to be a guarantee of expected in-track performance.

Direct-fixation procurement and construction specifications have largely been modeled on past projects since the first implementation; therefore, the industry has stated a need for an independent review of common direct-fixation qualification specifications and construction specifications.

Central to these concerns is the industry’s uncertainty as to whether specifications relate design intent with direct-fixation performance expectations.

Addressing these concerns is the underlying theme of this report. The relationships among direct-fixation fastener parameters, the specifications, and expectations for long-term performance are central to all other issues. The subsection “Discussion on Basics” in Part A, Section 1, Direct Fixation Track Design, presents a general view of track mechanics that ballastless track systems can affect, along with mechanics beyond the capability of these devices.

“Discussion on Basics” provides perspectives on the influences of fastener properties, track design, and specifications on track mechanics and how practical variations in fastener parameters and variations in manufacturing and construction may create deviant performance. “Discussion on Basics” also includes broad insight on key specification requirements and inherent limitations in some requirements, particularly laboratory tests.

“Discussion on Basics” is the prelude to the detailed design issues, methods, and data in the balance of Part A, Section 1, Direct Fixation Track Design.

Section 1, Direct Fixation Track Design, is the framework for subsequent sections of Part A, which provide examples of direct-fixation specifications along with commentary on each specification. There are three specification sections in Part A:

- Direct-fixation procurement specifications (Section 2),
- Direct-fixation test specifications (also referred to as “qualification tests”) (Section 3), and
- Direct-fixation track construction specifications (Section 4).

A fifth section in Part A is an example concrete specification, considered to be a highly useful reference complementing discussions of construction issues important for direct-fixation track design and construction.

The technical perspectives in Part A are formed in large part by a body of research work performed by Battelle Laboratories.

The industry, including an international agency, commissioned Battelle in three separate programs between 1995 and 1999 to quantify ballastless track product characteristics including stiffness and dynamic response among other important parameters. The characterizations were performed on every major type of ballastless track product except embedded rail track and embedded wood tie track. Part B, Final Research Report, summarizes the results of those studies.

With the array of ballastless track types, confusion has arisen on terminology for fasteners, track configurations, and some esoteric terms that describe materials. Appendix A to Part B provides a complete, cross-referenced glossary of ballastless track terminology.

The goal of this report is to bridge research and practice in order to address industry concerns and provide an informed basis for the continued evolution of advanced track forms.

Abbreviations used without definitions in TRB publications:

AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
IEEE	Institute of Electrical and Electronics Engineers
ITE	Institute of Transportation Engineers
NCHRP	National Cooperative Highway Research Program
NCTRP	National Cooperative Transit Research and Development Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
SAE	Society of Automotive Engineers
TCRP	Transit Cooperative Research Program
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation