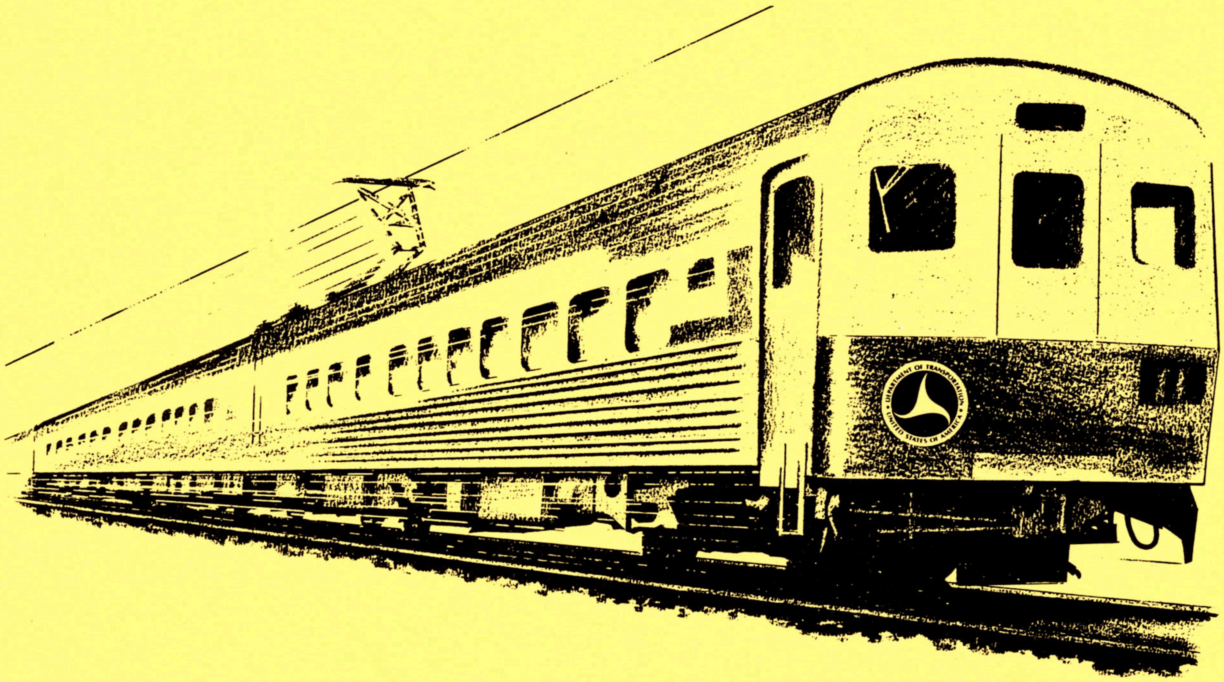
THE KANSAS TEST TRACK



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OFFICE OF HIGH-SPEED GROUND TRANSPORTATION

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16. Abstract

The Federal Railroad Administration and the Atchison, Topeka & Santa Fe Railway Company are jointly sponsoring the construction of a test track as part of the railroad's heavy tonnage main line in Kansas. The objective of the project is a determination of the levels of increased train stability provided by 8 specimens of incrementally improved track support. A further objective is a definition of the cost-benefit relationship associated with each augmentation of stability. The various test segments are defined, associated instrumentation requirements are outlined, and progress to date described.

17. Key Words	18. Distribution Statement
Track stability, improved track structures, beam and slab track support, concrete cross ties, stabilized ballast, track instrumentation	Availability is unlimited. Copies may be purchased from the National Technical Information Service, Springfield, Virginia, for $3.00 a copy.

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THE KANSAS TEST TRACK

PREFACE

This report describes in a general way the features of a complex technical project. A deliberate attempt has been made to avoid technical detail, with the conviction that a modest level of interest can be stimulated beyond the engineering fraternity once the nature and potential benefits of the project are made clear.

In brief the project encompasses the construction and closely controlled observation of a railroad test track. The purpose of the venture is to determine the cost-benefit relationship of several methods of improving upon traditionally designed, conventional railroad track. Subjected to study will be several concepts of rail support offering the promise of greater stability under rolling loads and longer-term retention of this desirable characteristic than is possible of achievement with contemporary track designs.

While it is obvious that this test track will contain a variety of constituent components, no attempt will be made to evaluate the performance of these. In all cases, items of hardware will have been screened to eliminate the potential for unwanted behavioral intrusion into the concept evaluation process. Beyond ascertaining that this preliminary screening was indeed successful, no further consideration will be given most items of track hardware. The mere inclusion of any specific material or device in the test program means simply that the project's sponsors have assured themselves of adequate train safety margins implicit in the use of such devices or products. Further it will have been determined that such materials will minimally influence the import of parametric observation. Recommendation of any product or material used in this program, if such recommendation occurs at all, will be based on ample performance data. This data will be revealed in the family of publications, some examples of which have already been issued (see bibliography following the text), that will be associated with this project.

The Kansas test track occupies but one position in the spectrum of track related investigations proposed by the Federal Railroad Administration. The concepts achieving singular success in this first phase will, then, be re-examined in the more severe circumstances of curved track on substantial grade. Performance in both phases must be constantly correlated with the track test work to be conducted at the Federal Railroad Administration conventional rail test loop at Pueblo, Colorado, and with tests being progressed on various railroads. Further, correlation is also required with the on-going theoretical track stability analysis occurring in several locations with the support of the Federal Railroad Administration.

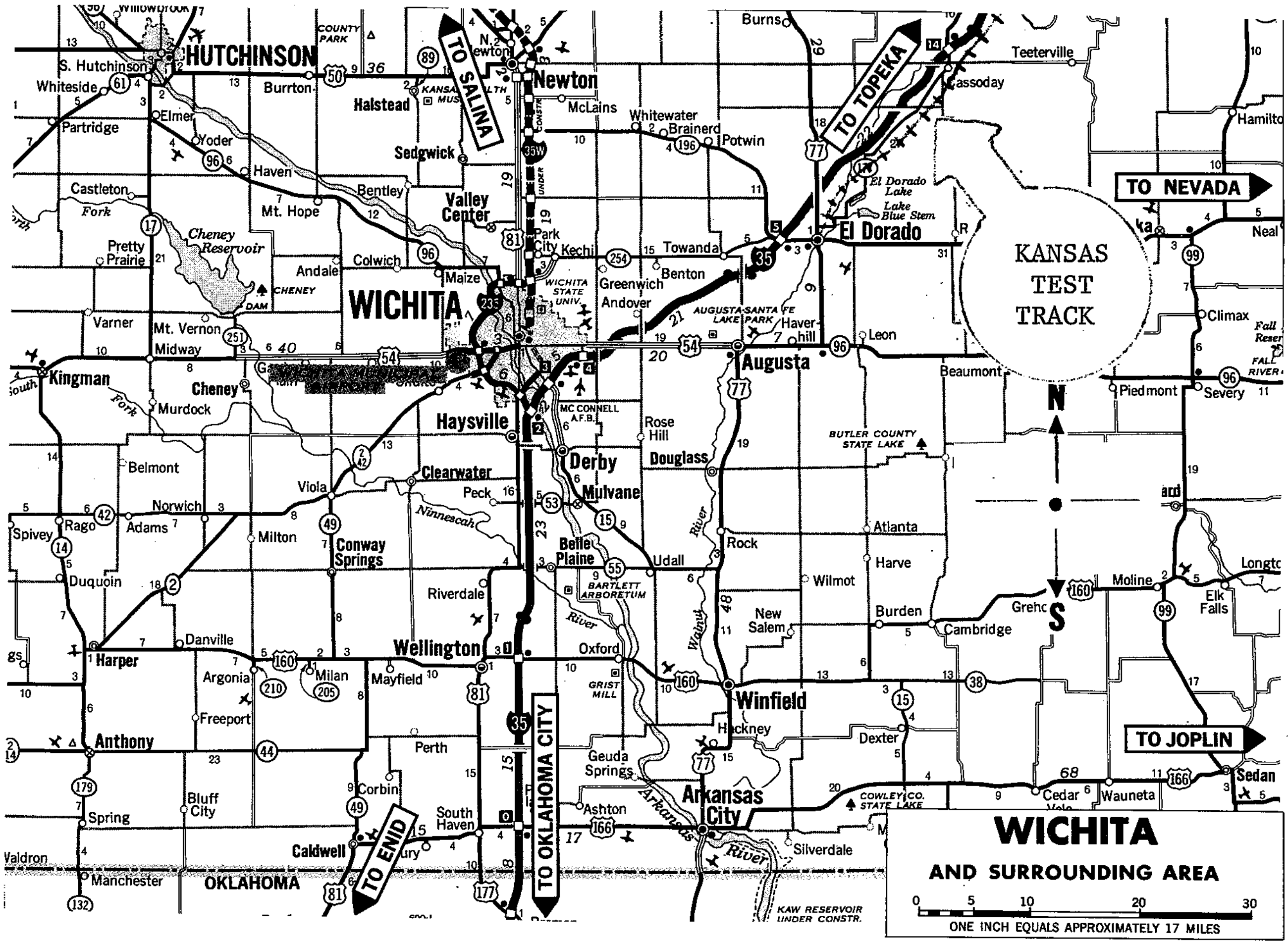

Figure I

General plan of southeastern Kansas showing the location of the test track.

The Kansas Test Track

PURPOSE

The Federal Railroad Administration (FRA) and the Atchison, Topeka and Santa Fe Railway Company (Santa Fe) are jointly sponsoring the construction and subsequent study of a railroad test track. This installation, the construction of which is now well under way, is located 45 miles northeast of Wichita, Kansas.[1] When completed in 1972, it will be cut into regular service and carry the bulk of the Santa Fe freight traffic between the mid-west and California, some 50 million gross tons per year and will be under intense investigation for a period of several years thereafter.

The purpose of this installation is to provide a facility that will permit the study of a series of railroad track support systems, each one of which is, in some degree, an improvement upon conventional wood ties, and ballast track. Conventional track has not changed its basic design to any marked extent in this century. This type of track has served the industry well over the years, but the recent increase in train speeds and car loadings have revealed inadequacies in this design of track. In spite of the introduction of smooth continuously welded rail on a large scale during the last twenty years, the advent of long, heavy and swifty moving trains has made the proper maintenance of this type of track an increasingly heavy economic burden for the railroads.

(1) This location is approximately 11 miles northeast of El Dorado; the railroad-designated locations of Aikman and Chelsea are to the northeast and southwest, respectively. The test track will lie between Highway 177 and the existing track. (see Figure I)

There is also a constantly growing interest in the development of truly high speed passenger service, particularly in regions of the country where the density of population is the greatest. It has already been shown that the type of railroad track we know today can safely support the movement of a self propelled passenger cars at well over 160 miles per hour - providing that the track is in a good state of repair. Whether this level of excellence can be economically maintained for a commercial operation involving fleets of fast trains is highly questionable.

BACKGROUND

The government recognizes an obligation to support innovation in the field of track construction and maintenance. The objective of this re-examination is to develop new concepts of support, some of which may be of immediate benefit to the industry and others that would provide a first look at the requirements for high speed passenger service. Two paths of action that could be followed simultaneously were evident. On the one hand, a theoretical study of the loaded response of conventional track had to be undertaken, so that its specific characteristics, favorable and otherwise, might serve as a guide to what would be desirable in a superior system. Having the results of this analysis one could proceed to a consideration of improved support for heavy loads and/or high speed operation, including the economics involved.

Following theoretical work, a site for the field installation of the new systems had to be located. There were seven criteria operative in the selection of this site:

1. straight, level track for the length of all candidate systems in order to defer, for the time being, the influences of major side thrusts and tractive forces; (grades and curves will characterize the next phase of this program)

2. right of way accomodating cut-over of traffic parallel to the regular line;
3. at least 40 million gross tons annually to accelerate the deterioration process and permit the early recognition of trends;
4. maximum steady train speeds;
5. reasonably severe environment, representative of that experienced by a large segment of the industry;
6. topographical profile that would not entail excessive excavation, fill, or structural duplication costs;
7. reasonably common roadbed material.

In the development of these criteria it was understood that the substitution of heavy tonnage moving at 60-80 mph would only approximate the dynamic input of more sophisticated trains travelling over the same track at greater speed. However, even if it is not possible to duplicate the precise loadings that would occur under the passage of high speed equipment it was felt that much useful information would accrue, the least of which would be an opportunity to compare one support system with another under the same loading conditions. The likelihood of reasonably similar, if not exact, long term response to the two types of dynamic loading is strong. Meanwhile, other FRA research and test projects will accumulate data on the forces associated with each type of operation by means of detailed investigation of the constituent parts, such as ballast beds, resistance to lateral displacement, containment of thermal strain, tie spacing and the effect of varying track modulus.

Following evaluation of candidate support concepts on this straight and level route, a smaller number of systems will be installed on curves and heavy grades.

Also, this experiment is being correlated with other track tests, such as the concrete tie series of the C&O/B&O at Noble, Illinois and the Linear Induction Motor Research Vehicle (LIMRV) trackage at Pueblo, Colorado.

In the spring of 1966, OHSGT requested proposals to undertake the theoretical inquiry. The stated objective was the generation of new ideas and designs for railroad track strucutres which would:

1. provide an inherently more stable ride for a train and/or
2. be more easily and economically installed and maintained than existing track structure designs.

The only important constraints placed on innovation in the presentation of proposed lines of inquiry were that standard track gage of 56.5" be retained and that the rail head contour remain as defined by present convention. The outcome was a series of reports which present the performance characteristics of a variety of rather rigid support systems, mainly some form of reinforced concrete slabs or beams.

During this period of analytic investigation, OHSGT was also active in the search for less elaborate improvements that might be made to present roadbeds. An especially attractive candidate emerged from this quest in the form of a substance that would bind stone ballast particles into a cohesive mass by means of an elastic compound. Extensive response and endurance testing of stone ballast treated with this compound has been conducted in the laboratory. (See DOT technical reports: 1) PB-179220

"Study of Methods of Stabilizing Conventional Ballast Using Polymers" 2) PB-192-720 "Stabilized Ballast Investigation" available through National Technical Information Service, Springfield, Virginia 22151). These tests have demonstrated improved resistance to displacement under loadings by factors of as much as 10 to 1 when compared with untreated material. What is not known is how ballast so treated will react in actual service.

Engineers responsible for maintaining track have been aware for some time of the potential for better track by substitution of concrete ties for wood. Because of their size and stiffness, concrete ties provide a more favorable distribution of loading to the supporting ballast than can be realized through the use of wood ties, and the much greater mass of concrete ties results in better resistance to movement under dynamic load than wood ties can offer. Many railroads have made service test installations of concrete ties. Several urban transit systems and foreign carriers have relied largely on concrete ties in the construction of new lines. One must bear in mind, though, that service conditions surrounding the use of concrete ties in these applications are less rigorous than similar track components seen in the United States as part of heavy tonnage main lines.

Despite wide spread interest, there is a reluctance to genuinely accept concrete cross ties for large-scale use. This stems in part from some unfortunate early experiences, the causes of which are not widely understood. Further, the actual response of concrete ties to in-track dynamic loadings has not been thoroughly investigated. Pure service testing is time consuming and, in the final analysis, less meaningful than test procedures which use suitably placed instrumentation to describe actual stress history. With the passage of time, it is possible to observe the evolution of certain effects in a service test installation, but the causes of these effects can only be inferred in the absence of data coming from a carefully designed program of instrumentation.

TEST SITE SELECTION

When candidates for a useful series of field trials had been identified, the Department was fortunate in arousing the interest of the Engineering and Operating Departments of the Santa Fe. They shared the concern of the FRA staff in contemplating the apparent zenith which conventional track is approaching at a time when traffic demands are revealing inadequacies at a level of maintenance which can be afforded.

Consequently, the Santa Fe extended an invitation to construct the test track on their property if the site selection criteria could be met. Seemingly, on so extensive a railroad (13,000 miles) this would not be difficult, but passing this half continent span of trackage through the sieve of the criteria produced just two locations; one in eastern New Mexico and the other in southeastern Kansas.

Inspection of the two sites revealed wholly disparate ground conditions. In New Mexico the gradient of the existing track is virtually level and, being constructed on slight embankment throughout, obviously introduced no cut-fill problems. Area soil is quite homogeneous, top soil being a brown silt of slight clay content averaging 2 feet in depth. Below this layer exists a sand, very silty and fine grained, to a measured depth of

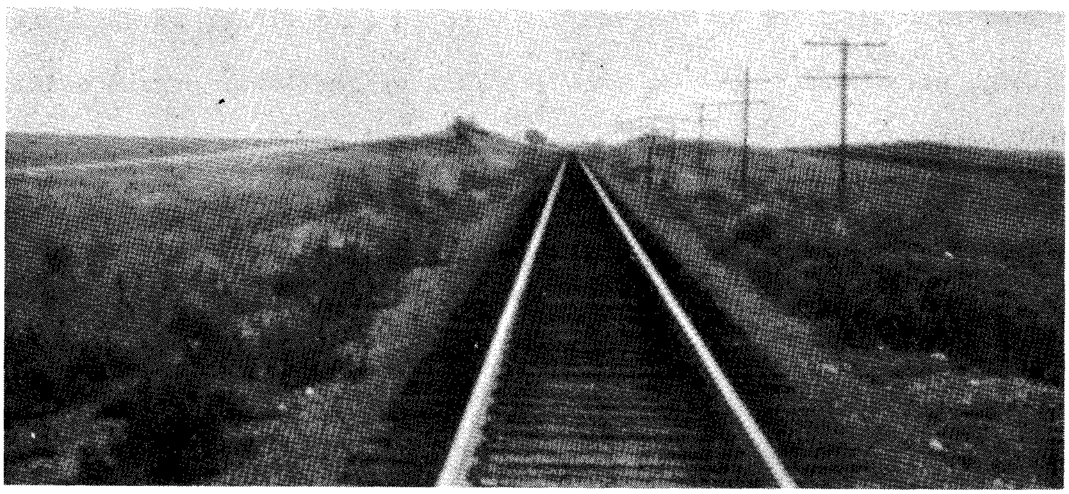

Figure II

View looking northeast showing terrain prior to start of construction. The test track center line will be 30 feet to the left of the present main track. State highway, K-177, appears farther left.

4 feet. Cement stabilization of the upper layer material could produce an ideal foundation. Underlying the work is a calcareous deposit of undetermined depth. This material, identified as caliche and indigenous to the southwest, closely resembles coral.

Temperature variation, annually, might be expected to range from - 10°F to 110°F. As the yearly rainfall averages 17", this part of the country is classified as semi-arid. Despite cold winter temperature, the high permeability of the soil and lack of available ground moisture eliminates frost action as a track influence.

In Kansas, the Aikman site exhibits a different appearance. The gradient ranges from .38% to .41% descending to the southwest. More singular contrasts lie in topography and subsoil properties. The country is gently rolling plain which, of course, immediately suggests alternate cut and fill. (See Figure II)

A unique characteristic of this region is the presence, at a varying depth of 0'-10' below surface, of a limestone stratum of extensive depth. Between this material and the top surface are three layers of clay generally described here as silty, moist, and plastic. Any use of this material for embankment construction purposes must be highly selective and closely monitored. Nevertheless, it can be made tractable by the commonly employed techniques used when similar material is encountered and worked in highway and airport construction, where the anticipated unit subgrade loads are more severe than those expected under the structural portion of the test track.

The annual temperature range is similar to that in eastern New Mexico but the average annual rainfall is in the order of 35" to 40". Incidence of snow and ice is high. Soil properties scarcely promote mositure permeability so volumetric changes under frost action are common.

Selection was between the "ideal" location in New Mexico, where the influences of subgrade support and environmental variables would be minimal, and the Kansas site. The choice was Kansas, with the pragmatic realization that:

1. in Kansas the support under the present Santa Fe main line and adjacent thereto is representative of the conditions that are conspicuous in a large part of the industry;
2. in New Mexico there is some real doubt that the relative environmental blandness and uniform consistency of sub-support material would permit performance evaluation within a tolerable period.

With respect to the first, and in all candor, an experiment such as the one projected must have meaning to the railway maintenance craft in order to be crowned with a modicum of success: The results must have been obtained under conditions representing as wide a spectrum of common influence as any one place could offer.

As to the second point, genuine apprehension over a lack of data accumulation within a reasonable time period is warranted. Although it is realized that the term of this experiment will be measured in years, it is hoped that data trends will be apparent within 2-3 years and that early, tentative performance conclusions may be reached in the first year.

Further investigation under other constraints, curvature for example, will be indicated for the more successful performers and the sooner this is recognized the better it would be. Carrying out the investigation under uniquely salutory physical conditions will retard the rate at which change will occur; confirmation of this is evident in Santa Fe maintenance experience in this part of New Mexico.

SYSTEMS TO BE STUDIED

Having derived performance objectives for rigid concrete support systems, requiring a realistic examination of a ballast stabilizing agent, and the desirability of quantifying the behavior of concrete ties, a lay-out of test segments then had to be formulated. This procedure was dependent on the physical features presented by the agreed-upon location near Aikman.

Analysis of subsoil and surface conditions, the effect of these conditions on test segment objectives, the expected behavior of train consists in the vicinity of instrumentation, and many other factors led to the following distribution of 800 foot test sections: (this order, from east to west, is displayed on the first of two fold-out sheets at the end of text).

1. concrete ties having a below-tie ballast depth of 10 inches and a center to center spacing of 30 inches;
2. concrete ties, 10 inches of ballast, and c-c spacing of 27 inches;
3. concrete ties, 10 inches of ballast, and c-c spacing of 24 inches;

4. continuously (field cast), reinforced twin concrete beams;
5. continuously cast, reinforced concrete slab;
6. stabilized or "glued" ballast; (this segment will be similar, except for the ballast treatment, to the Santa Fe contemporary track,; it will however, be only 545 feet long because of inescapable site dictates);
7. pre-cast, reinforced concrete twin beams;
8. concrete ties, 15 inches of ballast and c-c spacing of 27 inches;
9. standard Santa Fe main track construction - as a control section to which all others will be referenced.*

A nominal test segment length of 800 feet was arrived by reference to data acquired in a recent investigation of freight car vibration carried out by the Federal Railroad Administration with the C&O/B&O Railroads. During this study, the natural frequency of response to vertical excitation (and suppression thereof) characteristic of a conventionally sprung box car was determined. These values were useful in calculating the period of

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*Santa Fe specifications for main track construction in this region call for:

1. use of continuously welded, 136 pound rail with 1440 foot rail string ends field welded;
2. use of 7" X 8" X9'-0" hardwood, treated crossties spaced at 19.5 inch centers;
3. a minimum of 10 inches of crushed, ferrous metal slag ballast beneath the bottom of ties.

time and, thus, the distance along the track required to witness virtually complete attenuation of car response to discrete vertical perturbation for typical cars. It is desirable that each car of a train consist be responding, in the vicinity of the instrumentation to the test segment being observed and not retain evidence of earlier stimulus. Probably the strongest of the undesirable vertical inputs will occur as a threshold disturbance when entering a test segment. This effect is largely diminished by the choice of 800 foot segment lengths and the prescribed location, within this distance, of instrumentation arrays.

The test program devoted to a consideration of concrete ties has the modest, but useful goal of examining the influence on track performance of three increments of spacing and two of ballast depth. There are no firm data available that discuss these rather fundamental parameters. Yet, each have a strong bearing on the economics of track design. Additionally, the flexural reaction of single ties to load will be determined. This will afford tie designers a matrix of information more complete than has been available. Particularly this is true in the matter of torsional response of ties to service loadings where variability of tamper-induced compaction beneath ties may exist, an aspect of tie behavior heretofore largely overlooked.

This data emanating from the Kansas test track will complement the conclusions arrived at via other test installations, those being primarily of a service test nature. Pre-eminent among these other investigations is the carefully installed and closely observed C&O/B&O three-specimen test at Noble, Illinois. The Western Pacific Railroad has a service test under observation at Thornton, California. In 1971, and apart from the Kansas test track, itself, the Santa Fe installed several thousand concrete ties of various designs in different parts of their extensive trackage. The Southern Railway has announced a serious interest in service testing. Altogether, considering the already large commitment of the Florida East Coast, Seaboard Coastline and Kansas City Southern Railroads, it is evident that the industry is increasingly concerned with concrete tie performance.

It is to this growing awareness and receptivity that the output of the Kansas test track concrete tie segments is directed.

The slab and beams may be anticpated to be very satisfactory performers - while suspect economically. They will be rather large, the slab measuring approximately 18 inches in depth by 8 to 9 feet wide and each of the twin beams about 18 inches deep by 30 inches wide. Even though the beams, functioning as pairs, will present lesser bearing area to the embankment surface when contrasted with the slab, the consequent stresses will lie within the supportive capability of the foundation materials. It is evident that if the twin beam concept can demonstrate a reasonable approach to the performance of the slab, substantial economy of material can be gained by relying on beams rather than slabs. The inclusion of pre-cast beams in this study is suggested for the case of installation in working track, avoiding long out-of-service periods for curing. Even though the final design of the beams and slab is not available at this writing, a close approximation of certain probable features is tabulated below.

	BEAMS	SLAB
Wt. per lin. foot	800 lbs.*	1700 lbs.
Bearing area per lin. foot	7.5 ft^2 (*)	800 lbs.

*beams considered as pairs

As has been earlier stated, there is no current understanding as to just how well the ballast particle binder employed in producing the stabilized ballast effect will perform under actual service conditions. Performance in the controlled conditions of the laboratory was extremely encouraging. For example, comparing test tie settlement when subjected to similar loads and supported either on untreated or treated ballast -

	Vert. load	Cycles of application	Maximum deflection
untreated	50k	3×10^6	0.98 in.
treated	50k	4×10^6	0.09 in.
(additional series)	50k	4×10^6	0.01 in.
	total	8×10^6	0.10 in.

	Lat. load		
untreated	2.5k	(constant motion incipient)	0.10 in.
treated	2.5k		0.074 in.*

*Max. lat. loading of 11.5k produced 0.125 inches max. elastic deflection with recovery to 0.060 inches of permanent strain upon release of load.

A complete discussion of the nature of the laboratory tests is included in Item 5 of the bibliography at the end of text.

Now it is necessary to determine how well conventional track incorporating this ballast particle motion dampening agent will function, over the long term, when exposed to the hostile climatic and service environment of the test track.

With the formulation of a test plan and the selection of a test site, the next step was to procure an embankment or foundation design and to define the instrumentation that would be included in the embankment. Clearly, embankment support performance under each of the test segments would bear directly on their ability to distribute the stresses of passing wheel loads. Consequently, proposals indicative of sound engineering practice and, yet, displaying the high order of resourcefulness necessary to produce an economical yet functional embankment and associated instrumentation system were solicited from soils engineering firms. Following an exacting evaluation of the proposals submitted, a soils engineering firm was retained and authorized to proceed.

EMBANKMENT DESIGN

The principal design objective was to produce uniform support of good quality, not superior quality. It is required that this objective be atainable using present construction methods, equipment, and locally available materials. It was also considered important to reduce to the absolute minimum the number of variables which might complicate the interpretation of track structure data. These requirements are necessary in order to make the findings relevant for application to existing roadbeds or to practical roadbeds that may be constructed in the foreseeable future.

The standard Santa Fe section was selected for the test embankment. This section has proven to be satisfactory based on extensive experience, and the relative advantages of slight modifications in embankment geometry are not readily discernable. The use of the standard section also affords the opportunity to compare the test section with the long-term performance of existing roadbed.

The principal design decision concerning embankment geometry was to establish the minimum depth of embankment which would provide essentially uniform support and dynamic response to the track loading. This was required regardless whether the embankment was founded on rock or overburden. A six-foot minimum embankment thickness was adopted. This decision was reached primarily on the basis of "pilot" vibration measurements carried out on the embankment support of the adjacent present Santa Fe main track in the summer of 1970. The materials of this embankment are quite similar to those employed in the foundation of the test track. These studies and the exercise of engineering judgement suggested a need for an embankment well in excess of three feet to minimize vertical embankment response. The judgement factor considers the results of the static stress calculations which indicated an appreciable increase in embankment stress due to shallow rock boundary.

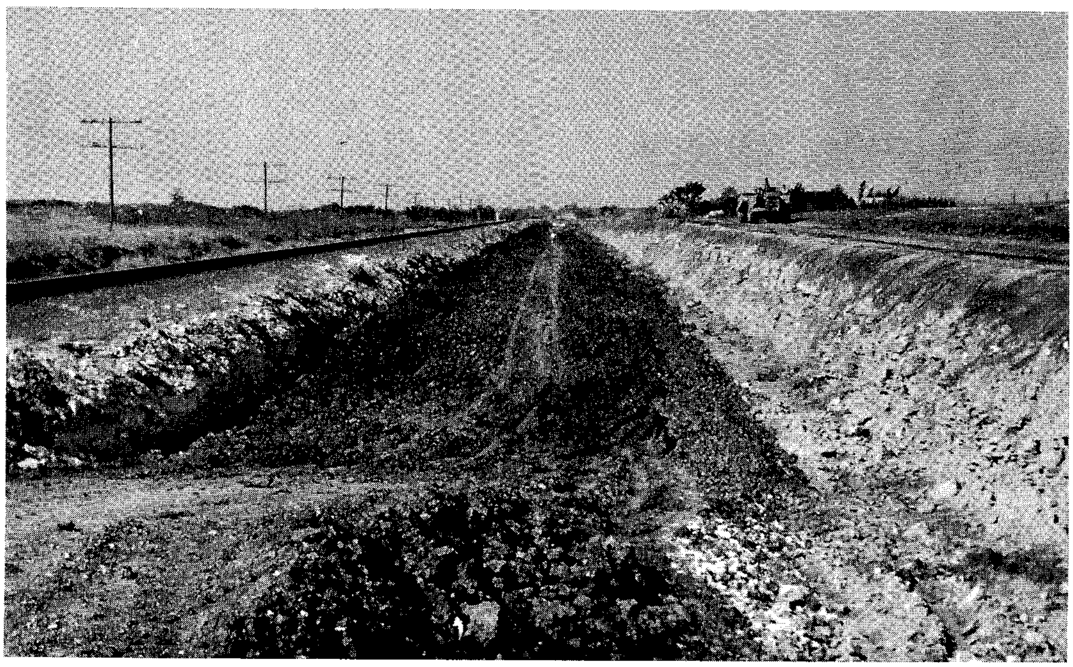

Figure III

Southwesterly line of sight along test segment 8, showing embankment material being dried to approach design moisture content prior to compaction.

The limiting constraint on thickness of embankment was cost. A four-foot minimum thickness would result in considerable variation in the thickness over the test track segment. A six-foot minimum thickness provides a reasonably uniform test section and very little additional benefit in uniformity is achieved by increasing the depth to eight feet. The additional cost of an eight-foot thickness compared to a six-foot thickness did not appear warranted. (See Figures III and IV).

INSTRUMENTATION OF EMBANKMENT

As stated, the performance of the track structures is influenced by embankment behavior. Therefore, it is necessary to observe the embankment response in order to evaluate track structure performance.

Embankment stress and strain under dynamic loading area of primary interest. However, it is very difficult to obtain valid stress measurements in earth so emphasis is placed on obtaining reliable measurements of strain. Long-term deformations and volume changes of the embankment are also of interest in this highly plastic clay embankment.

The required operational life of the instrumentation has not been definitely established. However, designs are based on an effective life of at least five years under the site climatic conditions. Where physically possible, the instruments are designed to permit maintenance or component replacement.

Each of the 9 test sections will have one principal instrument array. These main arrays will be supplemented by additional instruments spaced throughout the test section to verify that the performance of the embankment at the main array is typical of that particular test section.

The main array has been positioned near the west (downgrade) end of each test section on the premise that measurements will be made principally under west-bound rail traffic. This provides additional length of track for damping of non-uniform vehicles response which may develop between different test track structures before the main array is reached by west-bound traffic.

The main embankment array instrumentation includes vertical extensometers, portable horizontal extensometers which will be inserted in horizontal tubing embedded in the embankment, pressure cells, and moisture-temperature cells. With the exception of the moisture-temperature cells, the instrumentation has been adapted specifically for this project. Wherever possible, existing equipment or stock components have been utilized.

The distribution of embankment instrumentation is shown on the first fold-out sheet following the text. Details of a typical array of instrumentation are displayed on the second fold-out sheet.

Figure IV

Embankment in completed state including strain instrumentation. View toward northeast from shoulder of service road. (service road drainage outlet in foreground)

CURRENT ACTIVITIES

Translation of completed embankment design into an active construction phase was quickly accomplished. Bids for construction were solicited and this led to the selection of a contractor who started work at the end of September, 1970. Shortly following start-up, an unusually prolonged period of wet and cold weather prevented soil compaction at design levels of moisture content forcing suspension of this part of the work. The contractor was able to continue on the extensive rock excavation and did so with reduced forces throughout most of the winter.

The embankment, with all intended instrumentation included, was completed in September, 1971. In order to avoid the consequences of embankment material strength loss coming from frost action, the top six inches across the width of the subgrade have been treated with a 3% lime admixture and sealed with a cutback asphalt. Preliminary bearing tests, reinforced with early data from Corps of Engineers vibrational surveys, indicate that the goal of uniformity of properties has been satisfactorily attained. Recall that the initial objective visualized embankment support provided by common, less than ideal soil types. But, painstaking care will have been lavished on the formation of this embankment in order to develop an in situ uniformity of stiffness to the maximum extent possible. Valid comparison of test segment behavioral patterns is, therefore, not compromised by significant variability of embankment support. In-place embankment instrumentation is provided for the sole purpose of confirming this expected uniformity of embankment response to load. Decidely, this program does not anticipate, as an end in itself, a large inquiry directed toward the more or less commonly investigated parameters of soil foundation behavior.

Design of the three concrete support systems is proceeding toward eventual letting of a construction contract toward the end of December.

The Santa Fe will commence in the fall the first steps of construction of those portions of work lending themselves to the application of conventional track work techniques. This will include the distribution of first course ballast, cross ties, the construction of temporary turnouts at project extremeties and the delivery of welded rail.

Gerwick concrete cross ties and True Temper Clip-Loc fasteners are on order. The attachment for direct fixation of the rails to concrete support media will be provided by the Fastex Division of Illinois Tool Works. This fastener is designated by its proprietors as Fastall E-72 and, following diligent inquiry, was identified as unique in having current, independant test data indicating long term ability to survive repeated application of vertical E-72 loading.

TEST PROGRAMS

Completion of the test track will lead directly into a period of data collection. Following the diversion of traffic to the test track, the early response of the support system will be of interest. This early behavior, while possibly displaying evidence of support system performance less likely to be encountered as maturity in service is developed, must be made a matter of record. The duration of this initial data taking exercise will be determined by the incidence of significant change. Once system stability appears through the repeatability of data to have been established, the initial measurement phase will give way to routine - periodic observations.

The frequency of subsequent observation periods will depend on the rate at which change occurs. At this point, it is expected that these events will be at least seasonal, that is, four times each year. However, the schedule is sufficiently flexible to allow modification as experience is acquired.

As has been noted earlier, cumulative annual loadings over the test track will approximate 50 million gross tons. Under this severe traffic and given the variable stiffness of support implicit in the different test segment designs, a differential rate of segment change appears inevitable. This presents the interesting question of how to arrive at a decision to restore a degraded test segment to its original horizontal and vertical profile. Or, for that matter, in what terms are original profiles to be described in order to become targets?

A unique approach to the solution of these questions is being created around the capabilities of the FRA track measuring car. Instrumentation on-board this car permits the acquisition and storage of data descriptive of a track's geometric disposition in space. Also, accelerometer and displacement transducer measurements of the vehicle's speed-sensitive response to track geometric status may be accumulated. Appropriate data processing programs enable the display of these data in a variety of useful statistical formats such as exceptions, histograms, and power spectral densities.

The Santa Fe Railway will identify several locations where, in their judgement, their continuous welded rail track requires re-adjustment of vertical profile and horizontal alignment. Following passage of the track measuring car over these sectors of track, it will be possible to quantify the conviction of experienced maintenance personnel in defining for the Kansas test track that level of track degradation from which recovery must be made. Repairs will be progressed as and when individual test segments approach the unsatisfactory limit. Initial or "best" status of the test track will also be categorized by the measuring car, thus providing a constant target for each sequence of repair.

CONCLUSION

Strong, financially sound rail transportation is an essential part of the economic stability of this country. It is the hope and expectation of this project's sponsors that they are participating in an enterprise leading to a reduction in rail operating costs and an improvement in the efficiency of rail transportation.

Contractural participation up to mid-1971

1. Analysis and prescription of means for improving stability of track (conceptualization of the slab and beam systems):

   Battelle Memorial Institute
   505 King Avenue
   Columbus, Ohio

2. Development of the ballast stabilizing agent:

   Materials Research and Development, Inc.
   284 Adeline Street
   Oakland, California 94608

3. Laboratory investigation of ballast stabilizing agent:

   Research Center
   Association of American Railroads
   3140 South Federal Street
   Chicago, Illinois 60616

4. In situ vibroseismic survey of embankment properties expressed in terms of shear wave velocity and Poisson's ratio:

   Department of the Army
   Waterways Experiment Station
   Corps of Engineers
   Vicksburg, Mississippi 39180

The four preceeding organizations worked in direct relationship with FRA. With the establishment of the Santa Fe Railway as prime contractor on the project, all follow-on efforts were accomplished by others working as sub-contractors to the Santa Fe.

5. Preliminary soil borings for the comparative evaluation of two proposed test sites, Kansas and New Mexico:

   Hemphill-Shelby Drilling Company
   420 North Michigan
   Tulsa, Oklahoma 74115

6. Design of embankment and associated instrumentation:

Shannon and Wilson, Inc.
1550 Rollins Road
Burlingame, California 94010

7. Construction of embankment:

L. A. Knebler Construction Company
405 East 7th Street
Augusta, Kansas 67010

8. Design of reinforced concrete support systems (slab and beams):

Westenhoff and Novick, Inc.
222 West Adams Street
Chicago, Illinois 60606

9. Instrumentation design and installation, and data collection for all nine track structure systems:

Cement and Concrete Institute
Old Orchard Road
Skokie, Illinois 60076

10. Provision of concrete cross ties:

Ben C. Gerwick Company
P. O. Box 837
Petaluma, California 94952

11. Provision of the ballast stabilizing agent:

Phillips Petroleum Company*
Bartlesville, Oklahoma 74003

*acquired production rights from MR&D, Inc.

12. Source of direct fixation rail fasteners for reinforced concrete support systems:

Fastex Division
Illinois Tool Works
Des Plaines, Illinois

The Santa Fe Railway will supply and install all conventional track construction materials.

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1. STUDY OF NEW TRACK STRUCTURE DESIGNS

   Transportation Research Inst., Carnegie-Mellon University,
   Pittsburgh, Pa.
   Gurbachan S. Bhatia, James P. Romualdi, and Gerald R. Thiers.
   March 68
   PB 179 401

2. STUDIES FOR RAIL VEHICLE TRACK STRUCTURES

   Final rept. September 66-April 70, Battelle Memorial Inst.,
   Columbus, Ohio
   H.C. Meacham, R.H. Prause, D.R. Ahlbeck, and J.A. Kasuba
   April 30, 1970,
   PB 194 139

3. STUDY OF NEW TRACK STRUCTURE DESIGNS

   Phases I and II, 1966-69, Battelle Memorial Inst., Columbus, Ohio
   H.C. Meacham, J.E. Voorhees, G.J. Eggert, et al.
   (extensive discussion of details supporting some conclusions in
   Item 2, above)
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4. STUDY OF METHODS OF STABILIZING CONVENTIONAL BALLAST USING POLYMERS

   Final rept., Materials Research & Development, Inc., Oakland, Calif.
   F.S. Rostler, R.M. White, K. Nair, R.G. Hicks, & J.W. Newton
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5. STABILIZED BALLAST INVESTIGATION

   Final rept., Association of American Railroads, Chicago, Ill.
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   OF TRANSPORTATION

   Hemphill Corp., Tulsa, Oklahoma
   J.T. Eidt, B.D. Marks, and J.F. Stewart, April 1969
   PB 202-271

7. EMBANKMENT SUPPORT FOR A RAILROAD TEST TRACK

Interim Report - Design Studies
R.J. Dietrich and J.R. Salley. January 1971
PB 202-808

Note: Documents listed in this bibliography are generally available from:

National Technical Information Service
U.S. Department of Commerce
Springfield, Virginia 22151