REPORT 14

NATIONAL RADIO ASTRONOMY OBSERVATORY
POST OFFICE BOX 2
GREEN BANK, WEST VIRGINIA 24944
TELEPHONE ARBOVALE 456-2011

REPORT NO. 14
CONTRACT NO.
PAGE 1 OF
DATE Sept. 1, 1966

PROJECT: LFST

SUBJECT:

Discussions with Railroad Engineers

S. von Hoerner

For large telescopes, one of the possibilities for the azimuth rotation is a circular track on the ground, with a diameter comparable to the diameter of the telescope. A substantial fraction of the total costs, then, would be in these foundations. The costs would be reduced considerably, if just normal plain railroad could be used for the azimuth rotation: standard roadbed, ties and rails, and standard freight cars (without springs). The main question is whether it can be used concerning the accuracies we need.

In my first antenna paper (June 1965), I gave some estimates based on a telephone call to a railroad firm. With a maximum load of 30 tons/axle (450 tons/100 feet), the costs were mentioned with $ 80,000/mile; the accuracy after one year of normal use by trains was quoted with ±1/2 inch. For comparison, Bill Horne at Green Bank estimated the costs of a single heavy steel track, embedded in concrete and anchored to the ground, taking 300 tons downward and 80 tons laterally and upward; the result was $ 700,000/mile.

In order to obtain better estimates on railroads, I had several discussions on Aug. 29 with five railroad engineers of the New York Central System (466 Lexington Ave, New York, N.Y.). This meeting was suggested and prepared by J. Hungerbuhler. The results are given in the following.

1. Mr. Cunningham (General Discussion)

The ballast (gravel) used for the roadbed is not really "solid"; it provides for trains a certain (desired) "cushion", moving about 1/2 inch down if a train drives over it. If more rigidity is wanted, or if the ground yields too fast, a consolidation is used for the lower part of the roadbed by grout (mixture of sand and cement) which is poured in under pressure. For details, we should write to the firm Penetryn (38399 Pelton Road, Willoughby, Ohio; close to Cleveland). See attached letters (answer doesn't tell much).

A foundation of solid concrete is not recommended. It would not allow proper adjustments and maintenance, although the ground beneath it still would yield slowly. A really stiff and solid concrete foundation, thus, would need many pillars driven down to greater

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depth, if possible to solid rock; this would become extremely expensive.

Modern railroads mostly have welded rails, where the temperature stresses are taken up by the ties to the ballast. (Older rails leave open gaps between rail ends of about 1/8 to 1/4 inch.)

2) Mr.D.Perish (Costs)

For the complete track section (ballast, ties, tracks), for heavy loads, one has in the average about $ 15/foot for the material, and $ 1.5/foot for the labour; but the last figure might be about double for a small job, not connected to an existing railroad. In addition, one has about $ 1-2/yard^3 for grading (soil movement). On normal, relatively level ground, the total is about

$ 20/foot = $100,000/mile.

3) Mr.H.Curtis (Loads)

For heavy tracks (weight of (single) track 100 - 136 lb/yard), and for 21 inches between centers of ties, the maximum (downward) load is

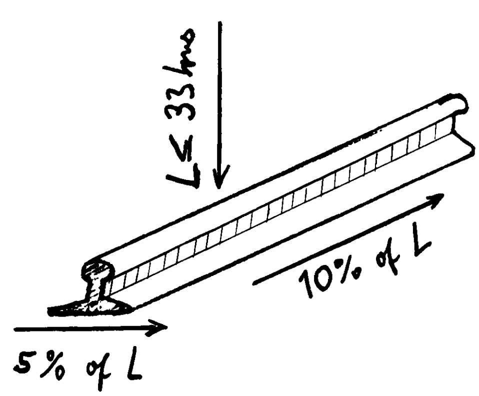
72,000 lb/axle = 33 tons/axle (two wheels).

With a minimum spacing between axles of 5 feet, this amounts to

660 tons / 100 feet.

The maximum forces in other directions depend on the load actually present:

10 % longitudinal (like accelerating a train)
5 % lateral (like a train in a curve).



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4) Mr. T. Scott (Maintenance)

For pssenger trains up to 85 miles/hour, the accuracy of newly built railway is mostly about 1/4 inch (grade and lateral), more accuracy is not needed. The cushion effect is about 1/2 inch in the average.

For heavy, high-speed trains, maintenance is necessary about every two years. Where the tracks are low, they are lifted, and more gravel is hammered beneath. These adjustments are 1/2 inch average and up to 1 inch; on soft ground occasionally up to 2 inches.

The cost of maintenance is about 400 $/mile.

5) Mr. R. Pattison (Welded Rails and Accuracy)

Modern railroads mostly use welded rails. The rails are anchored to the ties; the ballast reaches to the level of the top edges of the ties and it extends at least two feet sideways beyond both tie ends.

The maximum accuracy to be achieved by standard methods, for building and maintenance, is 1/8 inch (grade and lateral), and the cushion effect can be brought to 1/4 inch under heavy trains if wanted small.

The consolidation by grout would increase the costs by about 15 per cent.

For details and measurments on welded rails, we should write to the American Railway Engineering Association, Committee on Welded Rails, 59 Van Buren Street, Chicago, Ill. I have written, see attached letter, but no answer yet.

If some length of roadbed is produced with the same gravel and the same method on about the same soil, then the cushion effect, even after one year of use, should be about constant along this length of roadbed; within, say, 20 or 30 per cent.

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Summary and Conclusions

1. We could use either just normal roadbed with maintenance every two years, or reinforced concrete foundations on concrete pillars driven far down; but nothing in between. - The following holds only for normal roadbed.

2. Costs are about 100 000 $/mile for erection, and about 400 $/mile for maintenance.

3. Consolidation by grout only to improve soft ground.

4. Maximum loads. 4a. Down: L = 33 tons/axle = 660 tons/100 feet.
For example, a structure of 6000 tons should sit on at least 200 axles; this means 50 heavy gondolas with 4 axles and 35 000 $ each, which gives 200 000 $. The weight must be distributed over at least 1000 feet of track, which is the case, anyway.

4b. longitudinal = 10 % of L
lateral = 5 % of L

For example, a telescope of 200 m diameter, with a face-on wind of 25 mph, gives a wind force of 400 tons. If longitudinal only, the weight (telescope, gondolas ...) then must not be less than 4000 tons. If lateral, the weight must not be less than 8000tons.

The flat transit telescope will pick up about 2000 tons wind force in survival (110mph) which calls for some special anchoring in stow position. During observation, 25 mph, the wind force is 100 tons, which, even if lateral, demands only 2000 tons of weight which is the case anyway.

It seems that weight and wind force impose no serious problems.

5. Accuracy with standard methods can be brought to 1/8 inch for erection and maintenance, and is 1/2 inch after one year or two of use with fast trains. Regarding our low speeds, one might assume 1/4 inch = 6.34 mm.

If the tracks have the same diameter as the telescope, and demanding a pointing accuracy of 1/16 of a beamwidth, standard railroad is good for $\lambda = 10\ \text{cm}\sqrt{2/n}$, since we subtract two deformations at opposite sides of the track, and if the structure averages over n independent deformations on either side. We might suggest to regard $\lambda = 5$ cm as the limit. (Especially, if the surface gets deformed, too.)