

ACSM Student Chapter Offers Tape Comparison Service to Surveyors

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Introduction

The need for a local facility capable of verifying the accuracy of metallic surveying tapes to engineering standards has been recognized by The Burt and Mullett Student Chapter of the American Congress on Surveying and Mapping.

At Big Rapids, Michigan, the Ferris State College chapter has been involved with the design and fabrication of a tape comparison device since fall of 1973. The intent of this project was to provide a prompt calibration service, applying standards derived directly from the National Bureau of Standards, to answer the needs of local surveying and engineering organizations. Certain details of the chapter's work in achieving an inexpensive, portable, yet accurate, device for appraising the accuracy of virtually any common length tape may be of interest to state highway departments, municipal surveying organizations, and others.

The Design

The basic problem comprised the drafting of a procedure for readily comparing one known length, called a standard length, with another unknown length, called a field length. The standard length was to be determined by the National Bureau of Standards. The chapter's task was to design a valid means for comparing field tapes with the standard.

A committee comprising surveying students, Stuart Lakanen and Forrest Stanley, was chosen to consider several courses of action, including the installation of permanent monuments, set apart at an appropriate length, in the concrete floor of one of the school buildings. An installation of this sort would have provided an accessible standard length, for example, 100 ft., with which anyone could compare his field tapes, but sev-

eral adverse aspects in this plan had to be considered. First, dimensional changes in the building as the result of temperature changes might cause the monuments to move with respect to each other. Although such changes could be monitored in relation to building temperature, the risk of needless calculations would be introduced. Monuments installed at, say, 100 ft. would limit comparison of tapes of 100 ft. only. Equally objectionable was that permanence would prohibit portability. A relocation of the surveying organization would require the costly installation of new monuments essential for valid comparisons. Also objectionable was the fact that errors can easily be introduced in observing graduations on the standardized tape and referring these to intermediate marks on monuments, to be re-observed later when a field tape is compared. Last, but not least, a very critical item to a student chapter is cost. Drilling holes in the building's floor, installing monuments with a metal surface, and placing protective caps over the holes would involve much labor and demand special floor covers. For these reasons, the concept of permanent monuments having the precision of a standardized tape with which to compare field tapes became manifestly unacceptable.

A revised method involved supporting a standard tape in two separate fixtures, one containing a movable mark to be set and fixed at any specified graduation of the standard tape extremity. The standard tape could then be removed and a field tape installed. Any displacement between the set mark and the allied graduation of the field tape would permit the calculation of the field tape length at prevailing temperature, tension, and support conditions. Such a proce-

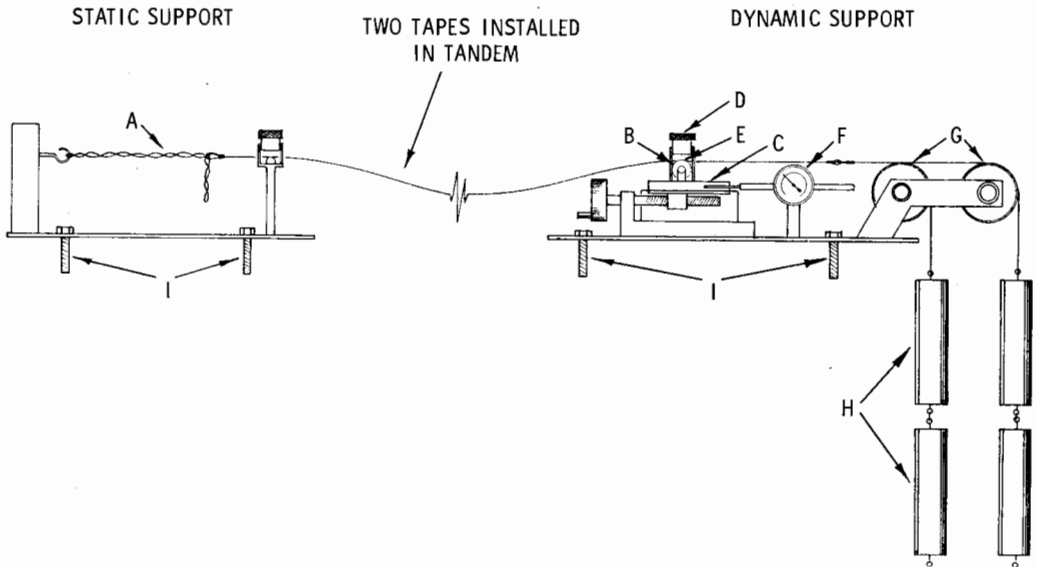


FIGURE 1.

ture affords significant advantages because a system of properly designed supporting fixtures can be portable as well as flexible. Also, it would permit any logical tape length to be compared, provided a standardized tape of corresponding length were available. Where tapes of 25 m, 30 m, 100 ft., 200 ft., or the like, required calibration, this would be especially useful. With the help of the machine tool and welding programs at Ferris State College, construction was started on a prototype early in 1974. However, in subsequent tests, the removal of standard tapes and installation of field tapes caused movement of the holding device, thus producing results which were unacceptable. By providing support for both field and standard tapes at the same time, this fault was eliminated.

The improved design permits comparison of the two tapes simultaneously held side-by-side. Not only does this overcome the inherent disadvantages of a permanent monument system, but even more important, the device is readily portable. It affords three distinct advantages: Direct comparison of the two tapes removes the risk of observational errors as is commonplace when using monuments, thus virtually eliminating any systematic error; various lengths can be compared without installation of extra monuments; and

time is saved because fewer observations are necessary. A drawing of the unit constructed by the chapter is shown in Figure 1. The design incorporates two basic parts: a dynamic support at which a tension load is horizontally applied on the tapes and a static support at which the tapes are rigidly held. At the static end, a user attaches one tape to a convenient link in a chain (A) and attaches the other tape to a turnbuckle located next to the chain. This arrangement permits the alignment of the end graduations on both tapes before measuring displacement of graduations at their other extremities. At the dynamic end, two roller bearings (B) support the tapes vertically under their end graduations. A small carriage (C) with an adjustable gib supports the roller bearings, magnifying glass with illumination lamp (D), and index mark (E). The motion of this carriage is precisely measured to 0.001 in. with a dial indicator (F), over a range of almost 2 in. Two large ball bearing mounted pulleys (G), which are vertically and horizontally adjustable, allow horizontal loading of the tape with either one or two ten-pound weights (H) attached to a nylon cord connected to each tape. Both static and dynamic supports can be attached to benches or tables, with bolts (I). This system will

accommodate a tape in full catenary as well as in multisupport condition with the appropriate bearing points. (See also Figs. 2 and 3.)

Determination of Length

Length of the field tape (L_{field}) at the time of comparison is determined by calculating the length of the standard tape (L) under prevailing conditions of tension, temperature, and support and measuring the displacement between end graduations (ΔL) of the two tapes at the dynamic support.

$$L_{field} = L + \Delta L$$

$$\text{where } L = L_s + A + B - C$$

The values of L_s , A , B , and C are defined as follows:

Standard Length:

L_s = Compared length of the chapter's tape at the National Bureau of Standards under specific conditions of tension (P_s), temperature (T_s) and in fully supported condition.

Tension Correction:

$$A = l(P - P_s) / AE$$

where l is the nominal tape length, P is the applied tension and AE is the product of the cross sectional area of the tape ribbon and Young's modulus of elasticity.

Temperature Correction:

$$B = l(T - T_s) \alpha$$

where T is temperature of the tape and α is the coefficient of thermal expansion for the steel used in fabricating the tape.

Catenary Correction:

$$C = 1 W^2 / 24 P^2 N^2$$

where W is equal to the total weight of the tape ribbon and N is the number of catenary spans.

The chapter will issue a certificate of comparison to those organizations submitting tapes for comparison with the chapter standard. As shown in Figure 4, certificates will contain the name and address of the owner of the tape, the make, the nominal length, a description of the conditions of comparison, and the determined length under these conditions. A statement of accuracy, indicating the standard deviation of the comparison, is also included.

Comparison of the standard tape at the National Bureau of Standards was made with a systematic error of not more than one part

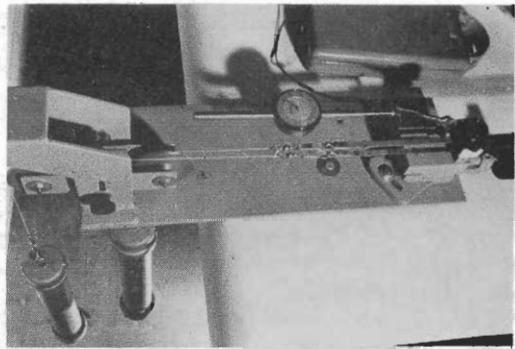


FIGURE 2. The dynamic support with two tapes subjected to ten pounds of tension. A battery box with a rheostat supplies current to a lamp that illuminates the tapes.

per 100,000 per hundred feet and a standard deviation of $\sigma_{NBS} = 0.003$ in. (0.0003 ft.). Based upon experience with the chapter's comparing device, standard deviations of the same magnitude as those claimed by the Na-



FIGURE 3. A view of two tapes located on the supporting roller bearings on the movable carriage. An observer views the two tapes located on either side of the index mark with the magnifying glass.

THE BURT AND MULLETT STUDENT CHAPTER

of

THE AMERICAN CONGRESS ON SURVEYING AND MAPPING

ISSUES THIS

CERTIFICATE OF COMPARISON

FOR THE FOLLOWING STEEL TAPE

No. 1

Owner Engineering Department
 City of Big Rapids
 Big Rapids, Michigan 49307

Maker Lufkin Rule Company

Tape Length 100 feet

Comparison was made under the following condition(s) with a standard tape compared at the National Bureau of Standards.

The indicated intervals will span the indicated lengths at 68° Fahrenheit when supported at the 0. and 100. foot points only.

Tension (pounds)	Interval (feet)	Length (feet)
10	0 to 100	99.996
20	0 to 100	100.005

The accuracy of the comparison has a standard deviation of 0.0004 feet.

DATE 14 February 1975

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Robert J. Smalley
 Robert J. Smalley

FIGURE 4.

tional Bureau of Standards are practically reproducible. Assuming a standard deviation of the chapter's comparison to be $\sigma_c = 0.0003$ ft., the standard deviation of the determined field length may be determined according to the theory of propagating errors as follows:

$$\begin{aligned} \sigma &= ((\sigma_{NBS})^2 + (\sigma_c)^2)^{\frac{1}{2}} \\ \sigma &= ((0.0003')^2 + (0.0003')^2)^{\frac{1}{2}} \\ \sigma &= 0.0004' \end{aligned}$$

Combining this random error with the original systematic error of the standard tape, a determination of the field tapes length may be made to within one part per 100,000 per

hundred feet with a standard deviation of 0.0004 ft.

Conclusion

An inexpensive portable device can be constructed that will provide an accurate means for verifying the lengths of field tapes. The static and dynamic supports assembled by the chapter have been made from scrap steel, transit magnifying glasses, a screw-driven carriage, dial indicator, and assorted small parts. A similar instrument can be constructed by surveying organizations at a minimum cost. The method of comparison has the definite advantage of comparing the field tape directly with the standard tape, thus eliminating the need for an intermediate length defined by monuments. This feature allows tapes of various lengths to be com-

pared, provided a standard tape is available. The method is portable and does not require a special area to be allocated for tape calibration.

The tape comparing services of The Burt and Mullett Student Chapter are available to all surveyors and engineers without charge. It is requested that the field tape to be compared is in good condition and free of kinks, and that the owner of the tape come in person to the college to witness the comparing procedure. Appointments for comparing field tapes may be made during the academic school year with The Burt and Mullett Student Chapter, ACSM, Attn. Professor Jens Otto Rick, West 231, Ferris State College, Big Rapids, Michigan 49307. Telephone: (616) 796-9971, Ext. 386. ■

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