TEST ON A BRAKE LINING DAMPER FOR STRUCTURES

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ABSTRACT

Tests were carried out on a brake lining damper intended to dissipate energy between parts of a structure having relative motion during earthquake attack. The device operates by the sliding of a steel plate clamped against a brake lining. Hysteresis loops for the damper showed peaks for the breakaway friction force, when the value of the force was up to twice that obtained for continuous movement. Also values of the coefficient of friction derived from the test were lower than those quoted elsewhere. Further testing is required prior to the use of the method in structures.

KEY WORDS: earthquakes, structures, energy absorbers, dampers, hysteresis, friction.

1. INTRODUCTION

The use of brake linings, clamped against a sliding plate to absorb energy between parts of a structure having relative motion during earthquakes, has been the subject of research by workers throughout the world with the object of providing in-plane damping for the panels of building structures. The work described in this paper was commissioned by the Ministry of Works and Development with a view to determining load/deformation characteristics under cyclic loading.

2. DESIGN OF DAMPER

The damper was fabricated incorporating brake linings supplied by Don Agencies NZ (Figs. 1 and 2). The central plate was made from bright-drawn mild steel, ground smooth to give a good surface in contact with the brake lining. The slots in the central plate accommodated a maximum possible slip of ± 5 mm in each half of the plate giving a total possible movement of ± 10 mm, frictional forces being generated on both faces of the plate.

Two of the bolts were calibrated with strain gauges embedded axially down a hole drilled from the bolt head. Other bolts were instrumented with triaxial strain gauges on the bolt head but this method was not satisfactory.

3. TEST PROCEDURE

3.1 Bolt Calibration

The two bolts were first calibrated in an Instron test machine to give a load/strain relationship. This was then related to the torque applied to the nut to produce a given strain using the washers shown in Fig. 1 below the head.

Four washers were used on each bolt with a view to keeping the bolt length as long as possible and thus reducing any strain loss which would occur through wear of the brake linings.

A calibration test was carried out on the instrumented bolts before and after the cyclic testing. The load in a bolt was increased in steps by tightening the nut to a specific torque and noting the strain on the bolt, which was converted to a force from the earlier calibration test. The resulting torque/load graph is shown in Fig. 3. The graph indicates that at the higher applied torques there was up to $\pm 10\%$ variation in the actual load induced in the bolts.

3.2 Cyclic Tests

The damper was set up in the test machine and the testing carried out at constant crosshead speeds, 100 mm/minute for the bolt torque of 67.8 Nm and 200 mm/minute for the higher torques. The torque on the bolts was increased in steps of 67.7 Nm up to 339 Nm and for each step the damper was cycled twice through an amplitude of ± 9 mm, i.e. the available movement in the two sets of slots was almost taken up. Finally with the bolts torqued up to 339 Nm the damper was continuously cycled 20 times. The resulting friction force/displacement loops are shown in Fig. 4.

4. RESULTS

The friction force is seen to peak up at the start of movement in each direction. Values of maximum and minimum frictional coefficients for movement in each direction for all the tests are given in Table 1, the minimum value occurring when motion was established. As two friction surfaces are involved, the coefficient of friction μ is given by:

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Fig. 1
Brake Lining Damper

R IN BRIGHT M.S.
GROUND FINE

Fig. 2 Details of Brake Lining Damper

$$\mu = \frac{\text{Measured Force (Fig. 4)}}{8 \times \text{single bolt load (Fig. 3)}}$$

Evidently, sliding occurred first in one half of the device and then in the other, giving two peaks in the hysteresis loops. Peak frictional forces are about double the minimum values occurring when slipping had started on the tension part of the cycle, but only about half as much again on the compression cycle.

The hysteresis loops for 20 continuous cycles show up to a 20% loss in frictional force between cycle 1 and cycle 20, presumably due to wear of the linings.

5. COMMENT

The loops obtained in the tests on this absorber are apparently at variance with those obtained by Pall and Marsh (1, 2, 3) in Canada in that idealised rectangular loops, with no peaks, are shown by these workers. The high ratio of static to sliding friction obtained in the tests at PEL is unsuitable for a damper as chatter would be generated by the stick-slip action, and there would be resulting overstrength requirements for the structure. Tests by Loo and Upfold (4, 5) in Australia showed a little drop-off of frictional force as motion proceeded, but not as great as in the tests at PEL. The values of coefficient of friction in Table 1 are about half those quoted by Loo and Upfold and by Ferodo (6). The work of Loo and Upfold and the Ferodo literature appeared to suggest, however, that lower coefficients of friction would be obtained at the slower speeds used in the tests at PEL and further tests should be made at various speeds to show up the speed dependence, and indicate performance for a sinusoidal drive.

Nevertheless the shake-table tests of Pall and Marsh indicated that the use of this type of friction joint was beneficial to a structure in that there is a value of slip in the joints that corresponds to a minimum response in the building. They further concluded that their use in vertical joints between panels produced a better seismic response than do monolithic walls.

From the point of view of improving the device tested, it is desirable to make the clamping bolts as long as possible in order to reduce the friction losses during continuous cycling, or alternatively, fit two or three Belville (spring) washers to each bolt to ensure a reliable clamping force. Clearly movement is best concentrated in a single sliding element for a particular device and in as few devices as possible in a structure in order to minimise the number of possible stick-slip peaks.

6. CONCLUSIONS

1. Ideally further investigation is required in an endeavour to eliminate the peaky nature of the force/

displacement loops obtained in the tests and to confirm the values for the coefficient of friction at various speeds and for sinusoidal testing.

2. Tests by other workers indicate that the method is a viable one for reducing the effect of earthquake attack on buildings. Its adoption would no doubt depend on whether comparatively inexpensive slip joints can be manufactured.
3. Shake-table tests using model structures with and without friction joints would assist in assessing their usefulness and reveal any practical difficulties.
4. The loops for continuous cycling indicated a loss of approximately 20% of the friction force after 20 cycles, which characteristic could be improved by the fitting of longer bolts or Belville (spring) washers to the bolts.

7. REFERENCES

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TORQUE ON BOLTS = 67.79 Nm (50 lbf ft)

TORQUE ON BOLTS = 135.58 Nm (100 lbf ft)

TORQUE ON BOLTS = 203.37 Nm (150 lbf ft)

Fig. 4A Cyclic load-displacement loops.

TORQUE ON BOLTS = 271.16 Nm (200 lbf ft)

TORQUE ON BOLTS = 338.95 Nm (250 lbf ft)

TORQUE ON BOLTS = 338.95 Nm (250 lbf ft)

Fig. 4B Cyclic load-displacement loops.