Plate friction load control devices—their application and potential

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We have recently conducted a numerical study on the dynamic behaviour of a simple, vertical, cantilever structure involving a joint with friction-slip characteristics.[7] The investigation determined the response of the cantilever when it was subjected to a periodic horizontal ground motion. The purpose of the investigation was to obtain insight into the effectiveness of the friction-slip joint in reducing the strain energy demand on the structure and its effect on displacement limits. The cantilever investigated is shown in Fig. 13 and the friction law adopted for the friction-slip joint is shown in Fig. 14.

67. The friction law used is hypothetical but it recognizes that a drop in the coefficient of friction occurs with increasing relative velocity of the sliding surfaces. It was considered initially that such an unstable characteristic might lead to an unfavourable condition in the structure so that deflexions would become unbounded for most situations. Fig. 15 shows the first portion of a typical hysteretic loop that was obtained when a friction-slip joint was used. The slipping behaviour depends on the rate of descent of the relative velocity dependent law.

68. The beneficial effects of introducing the friction-slip joint are apparent in that the moment level at the base is limited. The behaviour of the system is therefore in accordance with the spirit of the Paper. However, it is recognized that our results are limited by the validity of the friction law assumed and work is proceeding on this aspect.

69. The Authors have carried out tests on the slipping characteristics of friction bolted joints; these are extremely valuable as there appear to be no other results available on this aspect of joint behaviour.

70. In § 30 it is not clear whether or not the testing machine was servo-controlled. If it was, would not a deformation mode of control be necessary to define closely the unstable behaviour shown in Fig. 7?

71. The jagged curves in Fig. 7 occur because the kinetic coefficient of friction μ_k is less than the static value μ_s. Whether it is due to a step function drop in μ_k or a velocity dependent drop cannot be deduced from the results. If it is assumed, however, that a slowly decreasing μ_k with increasing velocity represents the friction characteristic of the joint (e.g. Samson *et al.*[8]) it can be argued that the characteristics obtained may be different in a real structure.

72. The physical reason for the sudden drop in load carrying capacity of the joint may be that some of the strain energy developed in the loading system is released as kinetic energy on initiation of slip. As the mass of the loading ram is relatively small the slip velocity must be high and hence the drop in load capacity large. It may therefore be expected that the characteristics of Fig. 7 would be different if the mass of the unit were larger.

73. Such a large mass could be expected to be associated with a joint in a foundation containing a load control device. Therefore, in a real structure, providing the assumption of a slowly varying coefficient of kinetic friction is valid, it would appear that the load/slip characteristics of Fig. 7 would be modified; whether or not the same residual load would be obtained is uncertain.

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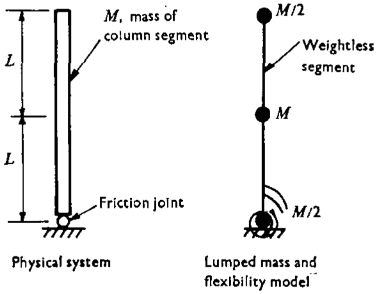

Fig. 13. Physical and idealized models

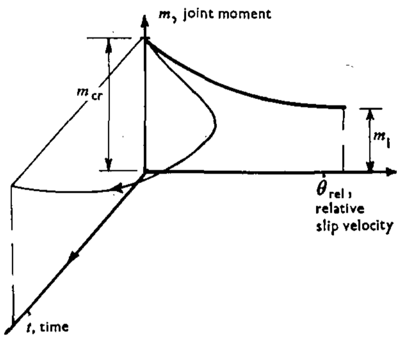

Fig. 14. Joint slip law

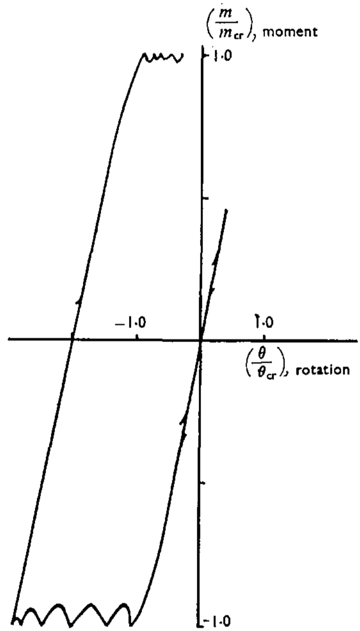

Fig. 15. Moment plotted against rotation

74. With reference to § 35, what is the experimental background to the statement that 'in the long term the load for slip appears to be unaffected by time'? Was this type of test carried out after repeated slip at the residual load? Were any tests carried out where only partial unloading occurred before reloading up to the slip load?

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The use of plate friction devices to absorb energy and limit the response of structures to, for example, earthquake forces, is one of many applications deserving exploration and we are encouraged to learn of the work done by Dr Schmidt and Mr Horoschun.

76. The tests described in the Paper and the machine used for them were chosen as relevant to the conditions under which the units were to operate in the immediate application. The effects of constant rate of strain were not investigated but, as mentioned in § 36, it was found that when load was applied so fast that continuous slip resulted, the load for slip reduced to 85% of that recorded for ordinary tests.

77. The influence of the structure on the release of energy and amount of movement of slip of the unit is recognized in the Paper. Although the mass of the structure must play a part once the unit is moving, its influence relative to other factors such as elasticity and the presence of alternative load paths has not been evaluated. In the control of static load, once the unit moves the length of each slip is not important for the purpose of load control. No evidence was found that the length of slip affected the residual load.

78. Tests on several units were performed at varying time intervals running into months, all after repeated slip at the residual load. The conclusion from these tests

was that after an initial variation that took place in a few hours there was no further change in the load for slip. No long-term test was performed without unloading after the first series of repeated slips.

References

7. Schmidt L. C. and Horoschun G. Interaction of material non-linearity and Coulomb slip on the dynamic response of a two-degree-of-freedom system. Paper presented to the fourth Australian conference on the mechanics and strength of materials, University of Queensland, 20–22 August, 1973.
8. Sampson J. B. *et al.* Friction behaviour during the slip portion of the stick-slip process. *J. Appl. Phys.*, 1943, **14**, Dec., 689–700.