V－140 ENHANCEMENT OF THE MECHANICAL BEHAVIOR OF FRP TENSION ELEMENTS BY THE CONTROLLED SLIPPAGE SYSTEM

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INTRODUCTION

FRP tension elements are coming into greater use in civil application to replace the conventional steel elements, mainly due to their durability, strength and lightweight. Much research is being conducted on their behavior and performance and lot of data could be gathered for many applications. However, the linear response of FRP elements besides their brittle nature puts a large obstacle for their reliable and/or economic utilization. If the FRP could have some yield-like behavior, its economy and reliability will be enhanced due to the enhancement of their mechanical behavior. In the current paper, an approach with experimental confirmation is suggested for achieving more ductile, reliable and economical FRP systems.

APPROACH AND POTENTIAL APPLICATIONS

In short, The approach depends on attaching a specific number of teeth to the perimeter of the tension element anchorage. A ring with equal number of slots is placed so that each tooth rests on the corresponding slot. The slot width is smaller than the outer width of the tooth so that under small load teeth cannot enter the slots. The system configuration takes the form shown in Figure 1. During the application of axial tensile loads on the FRP member, the teeth are pressed against the slots. Bearing pressure will result at the contact and, for sufficiently ductile material, yield occurs at some load P_y. As a result, the slot width increases and the tooth width decreases. At a trigger load, P_t, the teeth enter the slots and start sliding. If the slot ring is provided by a solid bottom, the teeth will stop at this bottom and rigid response of the teeth/slots assembly results. The three stages of slippage system response are represented in Figure 2 with the target load-deflection relationship as the solid lines A. When the slippage system response is superimposed to the linear response of FRP tension elements, as they are connected in series, the ductile response in Figure 3 results. It is obvious that an increase of the toughness is obtained as the shaded area that is proportional to the sliding length H, depth of the slot.The occurence of stages 1 and 3, in Figure 2, are certain whereas the behavior in stage 2 can assume three types. The two additional responses, besides the target response A, are shown as the broken lines B and C. In case A, the resistance forces inside the slot are equal to the trigger load and that causes perfect plastic response. In case B, the resistance forces are larger than the applied load but not large enough to cause rigid response and a response similar to strain hardening results after the trigger load. Both cases A and B are stable where the trigger load is at least kept the same during sliding. An unstable condition could result if the resisting forces inside the slot are less than the trigger load and the response C develops. The problem then becomes how to design the geometry and dimensions of teeth and slots so that a stable response develops and how to determine the trigger load. A computer routine for the analysis of this bearing/sliding problem was developed and two sliding systems were prepared with critical loads of 2.5-3.0 tons. The sliding system was slightly modified from that of Figure 1, for economical and processing considerations. The tested system is shown in Figure 4 where the sliding system takes the form of an adapter that can be attached to any anchorage. Such system might have potential applications in the field of Prestressed concrete where Figure 1 shows a modified anchorage. Second application could be the anchor rods of retaining walls A third application of the triggered slippage system is found in the FRP cables used for hanging and anchoring suspension and cable stayed bridges.

EXPERIMENTS AND RESULTS

Two prototypes were prepared according to the dimensions shown in Figure 5. The systems were made from 4 circular teeth outer ring and four straight slots inner ring. This is the simplest and most economic configuration of the slippage system. The teeth had 14 mm diameter and the slots were 13.5 mm in width. The slippage system has many parameters for study and, initially, the stiffness of slot ring and the teeth was chosen as a parameter as it directly affects the stability of the system at the trigger load. One of the prototypes had both rings made of stainless steel SUS 304 while the other had SUS 304 teeth and Aluminum A2017 slot ring. As shown in Figure 6, the system undergoes compressive loading when the anchored tension element is under tension. Therefore, compression loading was applied to both systems where load, deflection and teeth strains were monitored. The tests were conducted using an AMSTAR testing machine of 50 ton capacity at stroke rate of 0.18 mm/min. Experiment setup is shown in Figure 7. The load-deflection curves for both systems are shown in Figure 8 as well as bolt strain-load plots. It is obvious that both systems show satisfactory performance. However, the aluminum/steel (AL/ST)system shows more stable behavior (type B) than that of the steel (ST)system (type A). This was expected and can be understood by referring to the tooth strain-load relationships. In case of AL/ST system the teeth, that are moving through the soft aluminum, were only slightly deformed whereas for the other system considerable deformations occurred. This implies that after the tooth entered the slot, it kept its initial shape for AL/ST system and therefore the resisting loads are mainly due to

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bearing similar to the case before trigger load. In case of ST, the tooth was flattened and bearing area was significantly reduced from that before trigger load and resisting forces get major participation from friction that cannot fully compensate the lost bearing forces.

CONCLUSIONS

Controlled slippage system was developed to enhance the behavior of FRP systems by incresing their ductility. The system depends on the sliding of a group of teeth inside corresponding slots of smaller width. Two systems were designed and tested. Promising results were obtained and the effect of changing slot wall materials on the stability of the system was confirmed. Other system parameters are now under study.

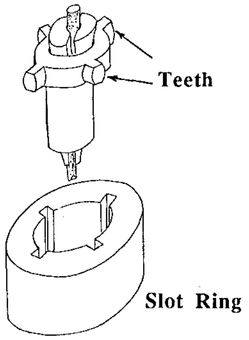

Fig. 1 Proposal

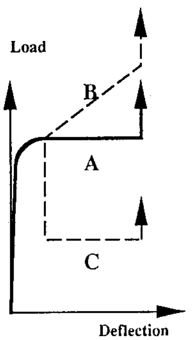

Fig. 2 Target Slippage Behavior

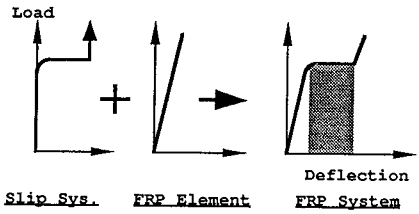

Fig. 3 FRP System Target Behavior

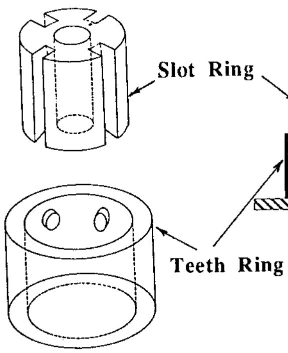

Fig. 4 Optimized System

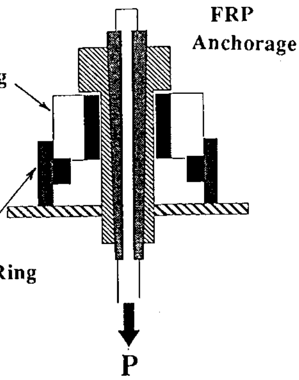

Fig. 5 Compression on Slippage System

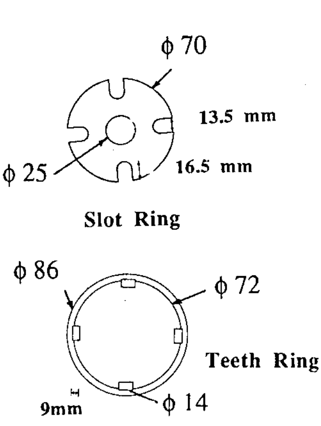

Fig. 6 Prototype Geometry

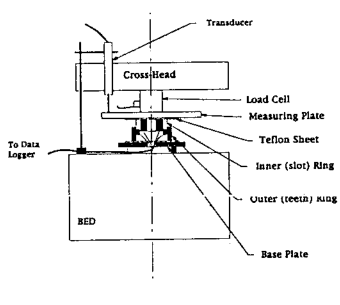

Fig. 7 Test Setup

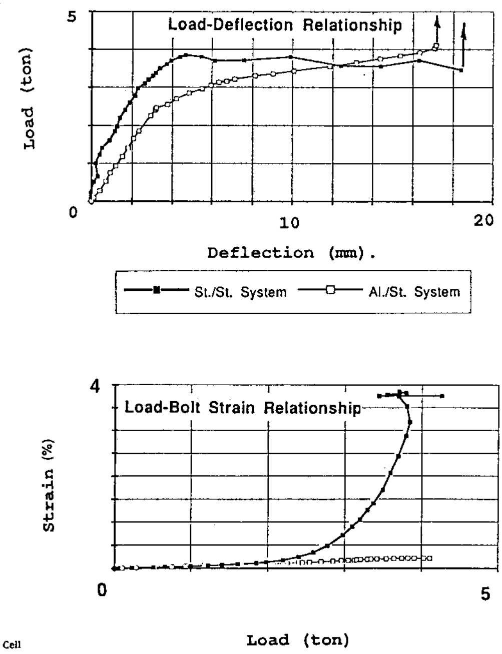

Fig. 8 Experimental Results