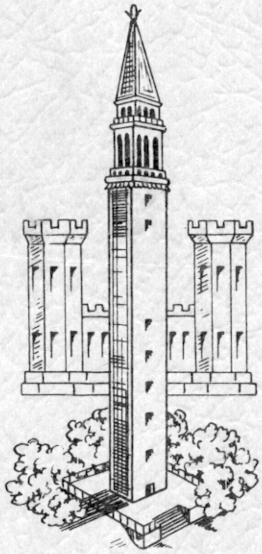
EFFECTS OF HEAVY SEDIMENT CONCENTRATION NEAR THE BED ON VELOCITY AND SEDIMENT DISTRIBUTION

By

H. A. Einstein and Ning Chien



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INTRODUCTION

The current descriptions of the sediment transport and. of alluvial channel hydraulics are based on the assumption that the presence of suspended sediment has no effects on either the characteristics of the flow or on the sediment distribution itself. Such a simplified assumption is valid at low and moderate flows, but often leads to significant errors at large discharges when a considerable amount of sediment is kept in suspension. In a sediment-laden flow the distribution of the sediment grains in the vertical is generally highly skewed, except that of the very fine particles. Near the bed there is a zone where the sediment' is heavily concentrated, while the concentration of sediment reduces towards the water surface. Since the turbulence which keeps the sediment in suspension is generated essentially at the bed, the local high sediment concentration naturally plays an important part in molding the turbulence pattern, resulting in a completely different flow as compared with that in clear water. The change in flow pattern, together with the fact that the settling velocity of the sediment particles is reduced by both the high concentration and concen tration gradient, as will be shown later, modifies also the local sediment distribution. It is imperative that the effects of heavy sediment concentration near the bed on both the velocity and sediment distribution should be considered and, if possible, incorporate& into the theories on sediment transport, if further progress is to be made.

The difficulties in studying this problem were numerous and often seemed to be insurmountable. On the one hand, many of the basic characteristics of the flow and of the sediment, for instance, the viscosity of the mixture and the settling velocity of the individual particles, are significantly changed by the presence of sediment in large concentrations. A survey of the literature indicates that past investigations have confined work on this particular problem to fine particles in or close to the stoke's range. There are indications that the effect of coarser particles may have a somewhat different character than that of the fine particles. For example, at the same concentration the mutual interference between coarse particles in retarding their settling may be considerably less than that among the fine grains.(1) So far as the writers are aware, there is no information available at present indicating how the presence of large concentrations of coarse particles changes the basic properties of the fluid and of the sediment. On the other hand, we know that the most important changes in the velocity and concentration profiles take place in a zone very close to the bed where the concentrations are the highest. Due to their interference with the flow most instruments cannot be used sufficiently close to the bed for the measurements of both the flow pattern and. of the particle distribution. Methods have been developed in recent years to measure the velocity and sediment concentration by optical or electrical means which do not call for the presence of bulky instruments interfering with the flow. Yet, these methods are still in the developing stage and are not sufficiently reliable for practical use as yet. In consequence of these two serious limitations the results presented in this report must be considered as preliminary and exploratory in nature, and should by no means be interpreted as the final answer. The variable8 involved, the difficulties encountered, and the general physical picture of the problem will be described. It is hoped that the results of this investigation may serve as a guide for future research along this same line.

APPARATUS AND METHODS OF MEASUREMENT

Experimental Equipment

The experiments were conducted in a painted steel flume 1.006 ft. wide by 1.17 ft. deep and 40 ft. long. The slope was adjustable by means of an especially designed jack, and the discharge was variable from zero to 3.0 cfs by changing the speed of the pump. Water and sediment leaving the flume were recirculated by a propeller pump located at the downstream end of the flume back to the upstream end through a lo-inch return pipe installed under the flume. Slightly downstream from the mid-point of the flume a 6-foot section of glass wall was provided on both sides for the observation of the particle motion. A single screen with 1 1/2 in. by 1 in. openings, a series of chicken wire screens, 8 honeycomb, and a floating board were used in most of the runs at the upstream end of the flume to reach equilibrium flow in a minimum length. Along the flume at 1 foot intervals measuring stations were marked. The useful length of the flume starts at sta. 4 of the upper end and terminates at sta. 34 of the lower end. The length of reach usually used in the analysis is from sta. 10 to sta. 32.

The discharge was measured in an especially built section of the return pipe, which was contracted on the two sides but leaves the top and bottom part uncontracted and operates like a Venturi meter. The position of the water