Erosion and Sediment Transport Measurement (Proceedings of the Florence Symposium, June 1981). IAHS Publ. no. 133.

Sediment sampling in rivers and canals

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ABSTRACT Studies to improve sampling techniques for bed and suspended load observations, in both low and high velocity flows, and involving collection and analysis of sediment data from rivers and canals, are being carried out at the Irrigation Research Institute, Roorkee. During these studies, we have developed and improved some samplers and analysed a large number of bed and suspended load samples collected at different depths and verticals from a number of rivers and canals under different flow conditions. It has been found that the mean suspended sediment concentration lies at 0.5 D in the vertical in the case of rivers, while for canals it lies at 0.54 D. The ratio of average suspended sediment concentration to that at the surface has been found to be 2.353. Studies on the problem are still in progress and an attempt is being made to develop a relationship between mean suspended sediment load and total sediment load.

Prélèvement d'échantillons de sédiments dans les canaux et les rivières

RESUME Des études en vue d'améliorer les techniques d'échantillonnage des sédiments charriés, sur le fond et des sédiments en suspension, tant pour les écoulements à vitesse élevée que pour les écoulements à faible vitesse, en recueillant et en analysant les données sur les sédiments des rivières et des canaux, sont effectuées à l'Institut de Recherches sur l'Irrigation à Roorkee. Au cours de nos études, nous avons mis au point et amélioré certains échantillonneurs. Nous avons également analysé un grand nombre d'échantillons de sédiments charriés sur le fond et de sédiments en suspension prélevés à des profondeurs et sur des verticales différentes dans plusieurs rivières et canaux sous différents régimes d'écoulement. On a trouvé que la valeur moyenne de la concentration des sédiments en suspension se situe à 0.5 D de la verticale dans le cas des rivières, alors que pour les canaux cette valeur se situe à 0.54 D. Le rapport entre la concentration moyenne des sédiments en suspension et celle à la surface est de 2.353. Les études sur ce problème sont encore en cours et on s'efforce de trouver une relation entre la charge moyenne sédimentaire en suspension et la charge totale sédimentaire.

INTRODUCTION

Total sediment load is transported by running water in different ways. The different phases of sediment transportation generally occur simultaneously in a stream, and there can be no sharp line of demarcation between them. However, total sediment load is usually divided into two categories, namely, suspended load and bed load. Suspended load is composed of fine particles and is predominantly a wash load; it is almost continually in suspension and is transported rapidly through the stream system. Bed load may be further divided into contact load and saltation load: the former slides or rolls, whereas the latter bounces and hops along the bed.

The size and concentration of sediment in a flowing stream generally increases from surface to bed, but also varies transversely in a river section. The magnitude of variation depends on the size and shape of the cross section, the stage of flow, and other stream characteristics. In turbulent flow, the direction of the current at a given point changes rapidly and haphazardly. Although flow at a point has a general forward motion, small areas of the flow may fluctuate both in vertical and horizontal directions over short time intervals. These fluctuations are irregular and haphazard, and a preliminary investigation of sediment distribution in a vertical therefore has to be undertaken before average concentration of the sediment may be computed.

SEDIMENT SAMPLING IN RIVERS AND CANALS

The first stage of sediment sampling in a river or canal is the selection of a suitable sampling site. The site should satisfy the following criteria:

(a) It should be in a straight reach of length at least 4 times the width of the channel, but not less than 150 m.

(b) The chosen reach should be stable, i.e. neither silting nor scouring.

(c) A normal section should be located in the middle of the selected reach.

(d) It should not be adjacent to hydraulic structures.

(e) It should be accessible, and preferably located near a village or town.

After the choice of site, the second problem is the selection of a suitable sediment sampler. A sampler should fulfil the following requirements:

(a) It should be streamlined to avoid disturbance of the flow.

(b) The velocity of inflow at the mouth of the sampler should be equal to the velocity of the stream.

(c) The mouth of the sampler should always face the direction of the current.

(d) The mouth should be outside the zone of flow disturbance set up by the body of the sampler, and filling should be smooth without sudden inflow or gulping.

(e) It should be able to collect samples at desired depths.

(f) It should be portable, simple in design and construction, and should require minimum care, maintenance, and repair.

For bed load measurements, the sampler is placed on the streambed to trap rolling particles. A variety of bed load samplers are available, but each sampler is not suitable for every site. The samplers of box or basket type are suitable for use in mountain streams with coarse gravel bed load. For sandy beds, the pressure difference type samplers seem to be the most satisfactory, because they equalize stream and entrance velocity. Flume studies have indicated that the Russian, UP Irrigation Research Institute (UPIRI), and Arnhem types of pressure difference sampler are more suitable for taking bed load samples, because of their greater efficiencies.

For suspended load measurements at a point in a vertical, the bottle silt sampler of the UPIRI type is most suitable for shallow depths and low velocities. For larger depths and velocities, the Turbidisonde L-80 sediment sampler is most accurate and suitable. USP-63, USP-61, USP-50 and USP-46 samplers are also suitable. For depth integrating sampling in a vertical, the USDH-48 sampler is satisfactory at low velocities and depths. For higher depths and velocities, the USD-49 and Turbidisonde L-80 are preferred because of their larger weight.

THE PROBLEM

The major portion of sediment load carried by rivers is generally removed during floods, which sometimes account for 90% of the annual transport. Therefore meaningful estimates of the sediment load carried by rivers have to be based on sediment sampling during floods. However, it is practically impossible using currently available samplers and techniques to undertake successful flood sediment sampling in major Indian rivers such as the Ganga and Yamuna. Existing sediment samplers are unsuited to the very high flood discharges and velocities of these rivers, and in addition it is often impossible to complete sampling traverses during spate conditions. Hence, studies are being undertaken at UP Irrigation Research Institute to improve the present sampling techniques for measurement of bed and suspended load in rivers and canals, so that the errors involved in estimation of total load, especially when the silt content is high, may be reduced.

PREVIOUS WORK DONE

Different organizations have recommended different procedures and techniques for sampling (United Nations, 1954, 1962; Joglekar, 1962; Uppal, 1966; Indian Standard, 1968; Central Board of Irrigation and Power, 1970). A perusal of these recommendations indicates that no guidelines have been laid down with respect to bed load measurement. In the case of suspended sediment load, the latest instructions of the Central Board of Irrigation and Power, New Delhi, are that it should be measured only at three points, whatever the width and condition of the river. This instruction does not appear to be rational, and more detailed studies are needed. With this end in view, studies are being carried out at the UP Irrigation Research Institute.

WORK UNDERTAKEN AT THE UP IRRIGATION RESEARCH INSTITUTE

Bed load measurements
A pressure difference type bed load sampler, illustrated in Fig. 1, has been developed for bed load measurements. The studies carried out to date indicate it has a very high efficiency. Bed load has been measured in various rivers using eleven, seven, five and three verticals. No significant difference, at the 5% level of confidence, has been detected between bed loads calculated from measurements in eleven and in five verticals, and it is suggested that sampling at W/6, W/3, W/2, 2W/3 and 5W/6, where W is the water width, will be sufficient for bed load measurements in rivers. In the case of canals, sampling at three verticals, W/6, W/2 and 5W/6, is sufficient for accurate measurements of bed load. However, it should be noted that it was practically impossible to measure bed load when the rivers investigated in the present study were in flood.

Suspended load measurements
In conditions of low flow depths, the USDH-48 sampler, which is depth integrating, has been found to be most suitable for measuring suspended sediment. Furthermore, with certain modifications (Fig. 2) the USDH-48 may be used as a point integrating sampler. When flow depths are large, the Turbidisonde (NEYRPIC) L-80 sampler is particularly suitable for suspended sediment measurements. Five verticals are sufficient for accurate sampling of suspended sediment in rivers, but again it is practically impossible to sample the entire depth of all the verticals under flood conditions.

The distribution of suspended sediment concentrations has been investigated for selected verticals in a number of canals and rivers at different discharges. It has been found that the mean value of suspended sediment concentration lies at 0.5 D in the case of rivers and at 0.54 D in the case of canals, where D is depth of flow in a vertical. Therefore, average silt concentration may be determined from sampling at these depths rather than from many points along the whole vertical. As already indicated, the silt content reaches a maximum during floods, and it is these periods which are of most interest for sediment sampling. In view of the difficulties in Indian rivers surrounding the use of conventional techniques for flood sampling, it is suggested that a satisfactory approximation of suspended sediment concentrations at such times may be obtained by taking samples from the water surface in the vicinity of bridge piers, using an ordinary bucket lowered from the roadway of a bridge. Turbulence in these zones will lead to more thorough mixing of suspended sediment, and in consequence concentrations may be more homogeneously distributed throughout the flow, so that a surface sample may be nearly representative of average suspended sediment

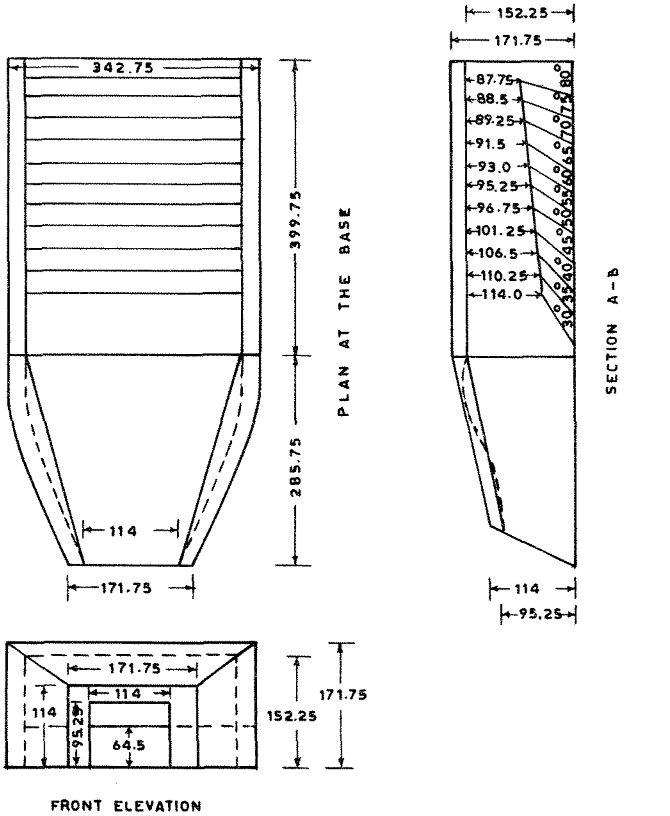

Fig. 1 UP Irrigation Research Institute type of bed load sampler.

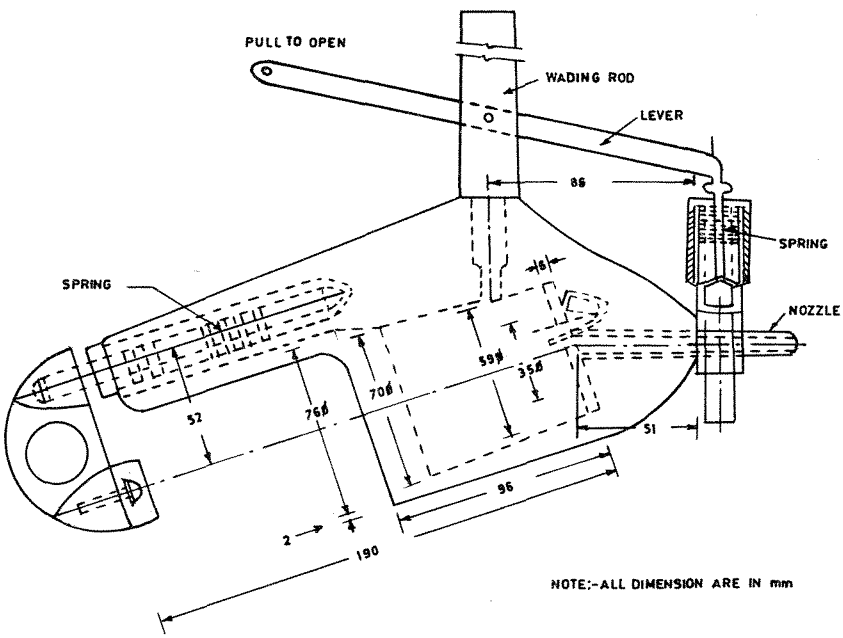

Fig. 2 USDH-48 depth integrating sampler modified to work as a point integrating sampler.

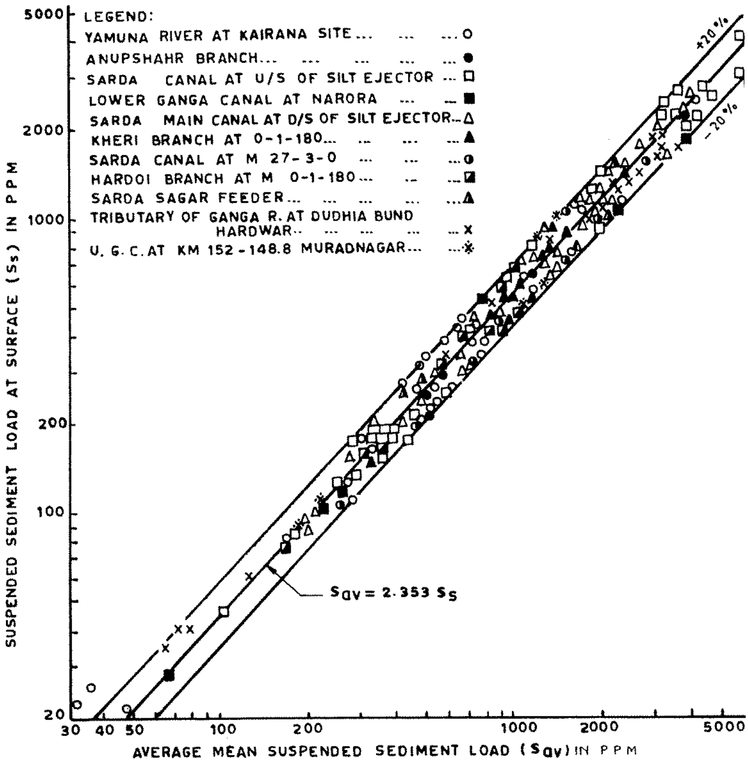

Fig. 3 Relation between average suspended sediment (ppm) and suspended sediment concentration at the surface (ppm).

concentrations at these locations. Furthermore, during floods it may only be possible to collect samples from the surface of the flow. A relationship between surface and average suspended sediment concentrations has also been developed from data collected in canals and rivers during stable flow conditions, and may be useful for estimating average suspended sediment concentrations in floods from surface samples alone. The relationship takes the form:

$$S_{av} = 2.353\ S_s$$

where S_{av} = average suspended sediment concentration (ppm), and S_s = suspended sediment concentration at the surface (ppm). A plot of this relationship is shown in Fig. 3, and it is apparent that the observed points lie in a range of ±20% from the suggested relationship.

Efforts are also being made to find a relationship between the total sediment load (bed and suspended load) and the average suspended sediment load. Such a relationship would be particularly helpful in estimating total sediment load carried by Indian rivers.

CONCLUSIONS

(a) The USDH-48 suspended load sampler, which is depth integrating, can also be used as a point integrating sampler with some modifications.

(b) The mean value of suspended sediment load can be found from single samples at 0.5 D in the case of rivers and at 0.54 D in the case of canals.

(c) For bed load measurements in canals, sampling using only three verticals located at W/6, W/2, and 5W/6, is sufficient.

(d) In the case of rivers, sampling both for suspended and bed load using five verticals located at W/6, W/3, W/2, 2W/3, and 5W/6, is sufficient.

(e) Sediment load carried by rivers during floods, when concentrations are at a maximum, cannot be determined using conventional methods and samplers. The following techniques can be used for sampling suspended sediment during such periods:

(i) Collection of surface samples from bridges across rivers, on the assumption that the silt content will be almost homogeneous throughout the total flow depth because of the great turbulence around bridge piers in high flows.

(ii) Development of a relationship between average suspended sediment concentration and that at the surface for stable flow conditions, which may be applied to surface samples collected during floods.

(iii) Determination of a relationship between total (suspended and bed) load and average suspended load from detailed sampling during stable flow conditions. This relationship may then be used to calculate total load for flood periods from average suspended load at high flows, the latter in turn being estimated from surface samples.

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