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VERTICAL ASYMMETRY OF RIVER CHANNEL CROSS-SECTIONS: A STUDY ON A MORIBUND DELTAIC CHANNEL

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ABSTRACT. – Vertical Asymmetry of River Channel Cross-Sections: a Study on a Moribund Deltaic Channel. Channel asymmetry has been quantified in three indices by Knighton (1981). His work has opened the wide porthole to have a search on every nook and corner of problems associated with channel asymmetry. The asymmetry of the river channel cross section is measured both horizontally and vertically. Horizontal asymmetry is well measured in index A*. Along with the horizontal component, the vertical component of asymmetry was incorporated in indices A1 and A2. In this present paper, the vertical asymmetry of river channel cross-section of a moribund deltaic channel has been examined through indices A1 and A2 and compared with ideal width-depth ratio.

Keywords: *Vertical asymmetry, vertical-oddity,* d_{max}, *channel asymmetry, centerline, mean depth*

1. INTRODUCTION

Asymmetry may be the eternal essence of nature that keeps it dynamic. It is true for river channel cross-sectional form. Most of the river channels are asymmetric (Leopold and Wolman, 1960) in nature. This is true even for a straight channel (Majumder, 2011) with successive bars of alternating pitch (Einstein and Shen, 1964; Keller, 1972). However, to quantify the degree of asymmetry of a river channel, Knighton (1981) has formulated three indices. To the end, he was influenced by the asymmetry measures by Sharp (1963) and Tanner (1967) and the work of Kennedy (1976) and Reineck and Wunderlich (1968) in similar fields. Knighton (1981) in his indices aptly considered the asymmetry components of one dimensional length of width and depth as well as two dimensional areas. But every work in the world is perhaps to be tuned to a better level, to open newer panes. The present paper does not aim to tune the indices into more perfect ones but to widen the panes, to shed light on more and more critical spectrums.

The first index of asymmetry, A* (Knighton, 1981), considers the differences in area between the two parts of the channel from center line. This index (A*) is very simple but very scientific to measure the degree of asymmetry of river channel cross-sectional form. This is very easy to apply because one can easily determine the channel central line and the cross-sectional areas to the right (Ar) and left (Al) of the channel

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centerline. As cross-section is a variable of two dimensions and as the formula incorporates the variation of area, it seems to be a good measure to the field. However, Knighton regretted that 'the measure does not explicitly include an indication of vertical asymmetry'. So he put forward indices A1 and A2.

$$A_1 = \frac{2x}{w} . \frac{dmax}{\mathrm{d}}$$

In this index A_1 he met his discontent and incorporated the vertical component. But what happened here is that the vertical depth, even being incorporated, has been ignored. Center line of a symmetrical channel resembles an object and its laterally inversed virtual image (Gour and Gupta, 1998). In a symmetrical channel, 2x/ w = 0. But d_{max} / d will show no asymmetry at all even if there is a great difference between d_{max} and d. In a horizontally symmetrical channel the value of (d_{max} / d), when multiplied with (2x/w) produces 0. Moreover d_{max} / d never be '0' which goes against the rule *'The lack of asymmetry in the cross-sectional profile should be signified by a value of 0'* (Knighton, 1981). d_{max} / d = 1 is only possible, when the channel shape is perfectly rectangular. In all other cases, for example, semicircular and isosceles or equilateral triangular, d_{max} / d is always greater than 1. Yet in these cases, the value of (d_{max} / d) is ignored by the value of 2x / w. Therefore, the concept of '*vertical asymmetry*' is not possible at all, at least theoretically until and unless a *standard mean depth* of a given cross-sectional area of a channel is defined.

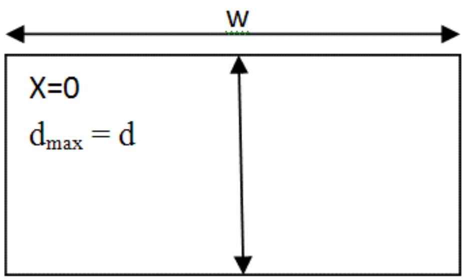

Figure 1. Symmetrical channel with d= d_{max}

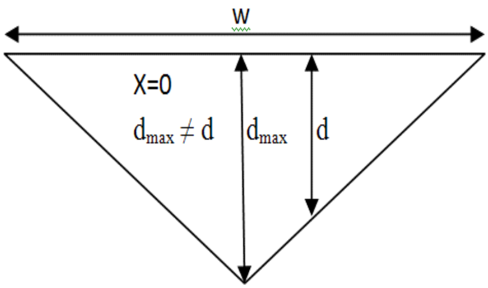

Figure 2. Symmetrical channel with d≠ d_{max}

$$A_2 = \frac{2x}{w} \cdot \frac{dmax - d}{d}$$

Here again, in a symmetrical channel, d_{max} = d is a '*sufficient condition for x=0'*, since it occurs only in a perfectly rectangular channel. In a symmetrical channel of any other geometrical shape like semicircular and isosceles or equilateral triangular, $d_{max} > d$ and $d_{max} - d \neq 0$. In this index also, the difference between d_{max} and d has been ignored if the channel is horizontally symmetrical. Therefore it seems that in equations of indices A1 and A2, although the component of depth has been incorporated, yet it has been remained insignificant. From this point, consideration of more critically tuned measures of vertical asymmetry becomes important. The present paper tries to measure vertical asymmetry from a different perspective incorporating the concept of ideal or standard depth of a channel with a given cross-sectional area.

Vertical Asymmetry

In figure 4 of his paper (Knighton, 1981), changes in the asymmetry indices, (A*, A, A2), for constructed channel shapes of equal area, width and mean depth has been shown as below where the dashed line denotes the channel centerline. The left-top horizontal arrow shows *'increasing horizontal asymmetry'* which is well illustrated in the figure. But left-top vertical arrow shows *'increasing vertical asymmetry'* which seems meaningless. Although the vertical depth (d_{max}) has been increased in successive channels keeping area, width and mean depth constant, but asymmetry is not visualised in vertical direction in column 1. What happened in reality is that, in every successive channels, the horizontal asymmetry has been increased in successive columns, not vertically. When (d_{max}-d) / d results 4/3, 2, 8/3, (fig. 3) mentioned in the first column, there is no vertical asymmetry at all.

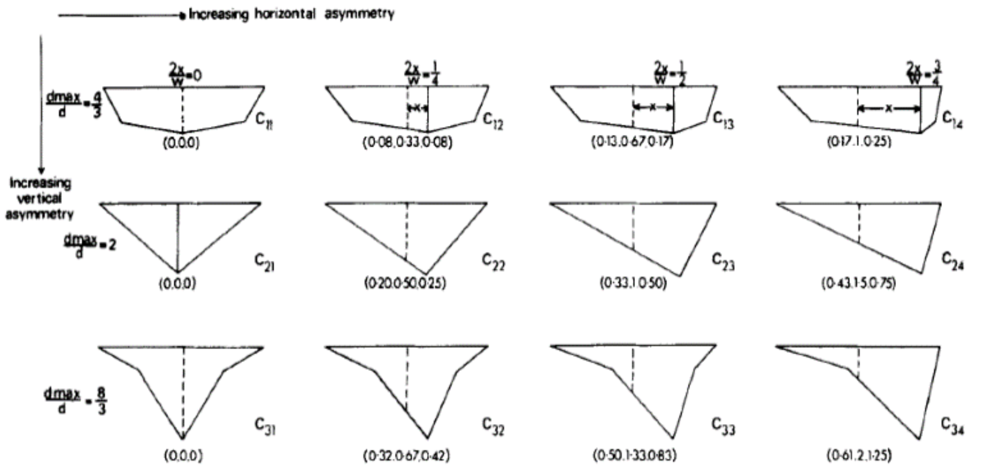

Figure 3. Increasing horizontal and vertical asymmetry (after Knighton, 1981)

If vertical asymmetry, better to term '*vertical oddity'* is to measure, then '*ideal and expected mean depth'* of a channel of given area, width is required to be calculated. In case of a triangular channel, $\check{D} = \sqrt{A}/1.52$ and $\check{D}_{max} = 2A/w$ (Das, 2014). Therefore if once the expected depth, width and d_{max} are known, then one can easily calculate the '*vertical oddity'* that is degree of deviation of observed mean depth from ideal and expected mean depth. Therefore vertical component of asymmetry can be measured by following formulas.

$$\bar{A}_d = (d - \check{D}) / \check{D} \quad (1)$$

where $\bar{A}_d$ = vertical asymmetry in mean depth.

If the channel has mean depth (d) equal to the expected mean depth ($\check{D}$), vertical asymmetry in mean depth will be zero. Positive value indicates greater depth and negative value indicates a mean depth shallower than ideal.

$$\bar{A}_{dmax} = (d_{max} - \check{D}_{max}) / \check{D}_{max}. \quad (2)$$

where $\bar{A}_{dmax}$ is the asymmetry in maximum depth.

In a semicircular channel, if $d_{max} = \check{D}_{max}$, vertical asymmetry of the channel is zero. Positive value indicates greater maximum depth and negative value indicates lesser maximum depth than expected.

In a single measure of vertical asymmetry both the parameters i.e. asymmetry in mean depth ($\bar{A}_d$) and asymmetry in maximum depth ($\bar{A}_{dmax}$) are to be incorporated. Therefore a product of the two may be adopted.

Vertical asymmetry

$$(\bar{A}_v) = \frac{d - \check{D}}{\check{D}} \times \frac{d_{max} - \check{D}_{max}}{\check{D}_{max}} = \bar{A}_d \times \bar{A}_{dmax} \quad (3)$$

Testing of equations

Taking 11 cross-sections (cs) of the river Jalangi (fig. 4), a moribund deltaic channel of West Bengal, India, vertical asymmetry was measured empirically. In all cases of eleven cross-sections, the observed mean depth (d) was less than the ideal mean depth ($\check{D}$) resulting negative vertical asymmetry in mean depth, as the average is -0.73. On the other hand vertical asymmetries in maximum depth were positive for cross sections 2, 3, 7, 9, 10 and 11, the average being 0.12. In the equation of A1, vertical asymmetry is measured as d_{max}/d. Average of d_{max}/d for 11 cross sections is 2.25 with maximum value of 5.79 and minimum value 1.15, which does not follow the basic rule 'index should have known limit '. In A2, vertical asymmetry is defined as (d_{max}-d) /d. Here the maximum value is 4.79 and minimum is 0.15 and it does not tell about 'known limit' of the index. As 'd_{max}' is always higher than'd' (except perfect rectangular channel), d_{max}/d and (d_{max}-d) /d will never be confined within 0 and ±1. The index value of '$\bar{A}d$' and '$\bar{A}dmax$' also suffer from the same problem. But in one way, '$\bar{A}_d$' and '$\bar{A}_{dmax}$' are preferred because in these measures, comparison with the ideal mean depth and maximum depth and observed mean depth and observed maximum depth is possible.

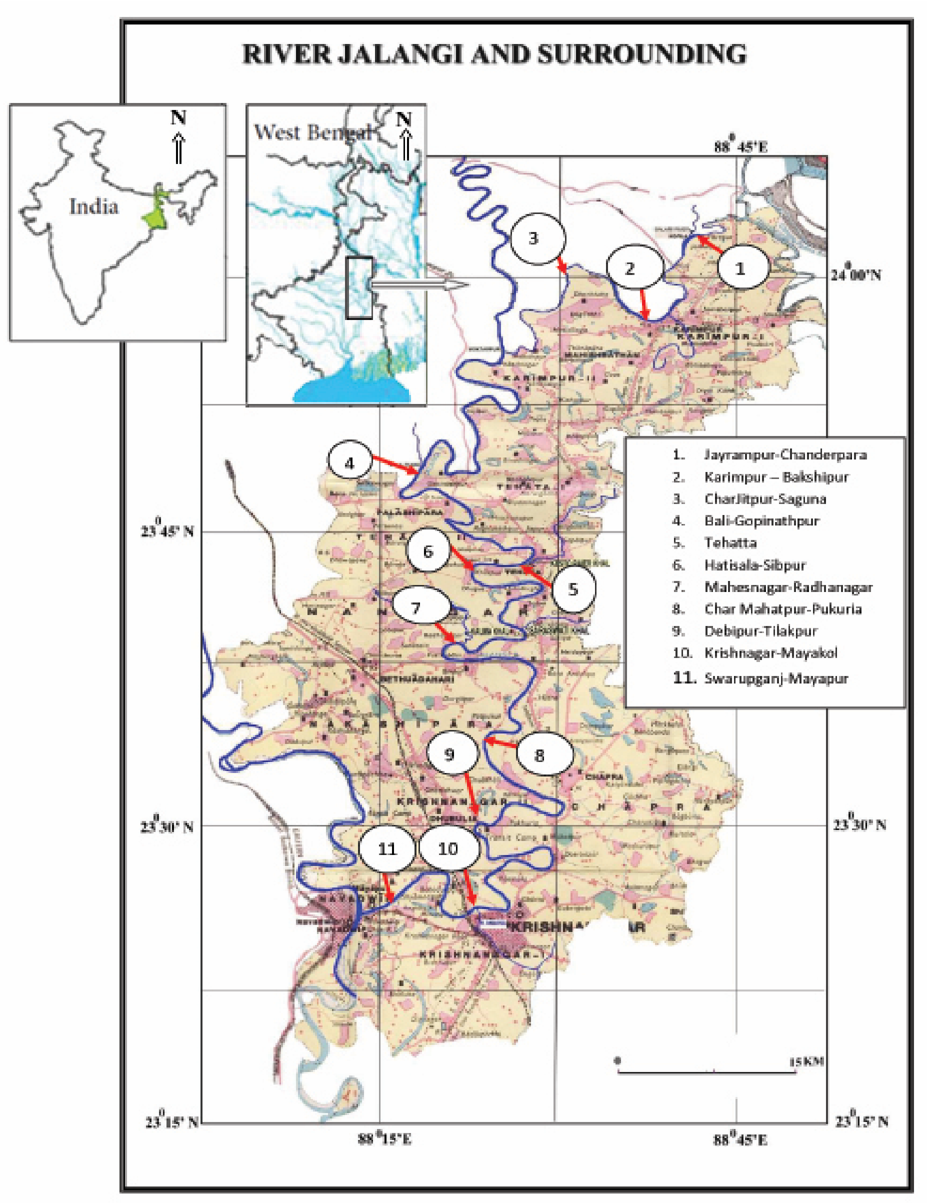

Figure 4. Location of study and sites of cross-sections

Table 1.

Different Parameters of Cross-sections of River Jalangi

Cross-section number	Area (Sq. m)	Width (w) in meter	mean depth (d) in meter	w/d ratio	$\check{D} = \sqrt{A}/1.52$	$\bar{A}d = (d-\check{D}) / \check{D}$	d_{max}	$\check{D}_{max} = 2A/w$	$\bar{A}_{dmax} = (d_{max} - \check{D}_{max})/\check{D}_{max}$	$\bar{A}v = \bar{A}d \times \bar{A}_{dmax}$	d_{max}/d	$(d_{max}-d)/d$
1	172.21	116.64	1.48	79.00	8.63	-0.83	1.70	2.95	-0.42	0.35	1.15	0.15
2	453.66	181.01	2.51	72.22	14.01	-0.82	5.30	5.01	0.06	-0.05	2.11	1.11
3	30.11	47.12	0.64	73.74	3.61	-0.82	3.70	1.28	1.90	-1.56	5.79	4.79
4	568.90	135.00	4.21	32.04	15.69	-0.73	7.80	8.43	-0.07	0.05	1.85	0.85
5	524.78	98.72	5.32	18.57	15.07	-0.65	9.20	10.63	-0.13	0.09	1.73	0.73
6	860.22	134.20	6.41	20.94	19.30	-0.67	10.30	12.82	-0.20	0.13	1.61	0.61
7	672.63	117.22	5.74	20.43	17.06	-0.66	11.90	11.48	0.04	-0.02	2.07	1.07
8	1016.32	184.00	5.52	33.31	20.97	-0.74	10.60	11.05	-0.04	0.03	1.92	0.92
9	687.99	144.40	4.76	30.31	17.26	-0.72	11.05	9.53	0.16	-0.12	2.32	1.32
10	827.68	144.04	5.75	25.07	18.93	-0.70	12.40	11.49	0.08	-0.06	2.16	1.16
11	786.24	124.20	6.33	19.62	18.45	-0.66	12.70	12.66	0.00	0.00	2.01	1.01
Average	600.07	129.69	4.42	38.66	15.36	-0.73	8.79	8.85	0.12	-0.10	2.25	1.25
SD	296.04	37.67	2.00	23.93	5.11	0.07	3.72	4.00	0.61	0.50	1.22	1.22
CV	49.33	29.04	45.16	61.89	33.26	-9.56	42.30	45.16	492.02	-477.00	54.16	97.58

2. CONCLUSION

The ratio of width and depth is the function of channel shape. But mere width - mean-depth ratio (w/d) does not define cross-sectional shape (Hey, 1978) even though it is a widely used index. So to have comparison, instead of simple width to mean-depth ratio, the comparison of observed mean depth and maximum depth with expected ideal value is more meaningful. The asymmetry of the river channel cross-section is the function of bed material, slope, volume, velocity, Renold's number, secondary flow etc. So to understand channel behavior, the meaningful knowledge of asymmetry is essential.

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