# 東南アジアの河川における交通能力に関する考察

## A DISCUSSION ON NAVIGATION CAPACITY OF RIVER IN SOUTH-EAST ASIA

PHAM Hong Son[1] Takashi ASAEDA[1] Yuzo AKATSUKA[1] VU Thanh Ca[1]

ABSTRACT; From the navigation view-point, the change in water discharge of river is one of the most important factors. Since the South-East Asian rivers are in the tropical monsoon region, this variation is normally large. For these rivers, water discharge is extremely small during the dry season, from Dec. to Apr., and large during the rainy season from July to Oct.. The difference of these two extremes of water discharges is high as 200 times for Irrawaddy river at Mandalay, 21 times for Mekong river at Kratie, 22 times for Chao Phraya river at Chao Phraya Dam and is supposed to be one of the highest among large rivers in the world.

Another important factor may be the river morphology, which is normally determined by the conditions at the annually maximum or bankfull discharge. As for the frequently flooding rivers, the conditions just before the bank collapse are influential. Most of the rivers in South-East Asia are among the meandering regime with the formation of alternative bars at both banks of the river. Thus the river bed morphology can be predicted empirically since the formulation of alternative bars can be modeled. These alternative bars form during season of high water level, and remain even after the water level reduces. Therefore, they may become obstructions for navigation during dry season.

The variation in the water level of South-East Asian rivers during one year can much affect the transport capacity, which may become critical during low-water period.
KEYWORDS; Navigation, meandering, bed morphology.

## 1. HYDRAULIC CHARACTERISTICS OF SOUTH-EAST ASIAN RIVERS

In attempting to study South-East Asian rivers for transportation purposes, it is most appropriate to adopt a hydraulic approach. Main characteristics of the South-East Asian rivers in mainland area are: seasonal discharge variation, flooding, meandering and tidal penetration far in land.

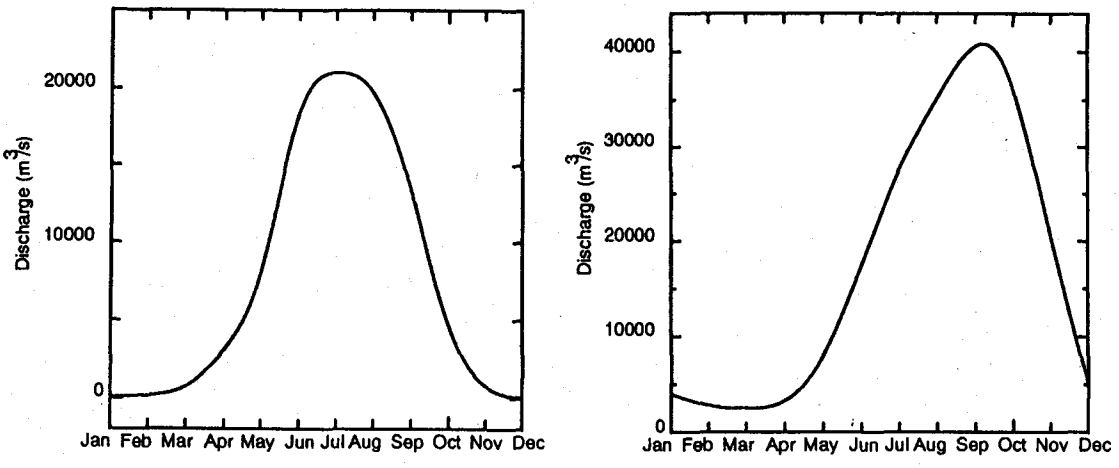
The climate of South-East Asia is governed by monsoons steady winds of low to moderate intensity that blow alternately from the north-east and the south-west. The south-west monsoon begins in May and continues until late September, then following a brief period of instability. The north-east monsoon from November to March. Except in the interior of the mainland of South-East Asia, maritime and equatorial influences are dominant.

The rainfall regime depends largely on geographic orientation and season in the area. From mid-May to October, the south-west monsoon coveys a great of moisture to the region. Many parts of the region receive more than 2000 mm of rainfall a year. The cool season, nearly rainless, lasts from about mid-November to mid-March.

The flow in the mainland derives largely from rainfall, its discharge in turn reflects the pattern of rainfall distribution over the year. Since the South-West monsoon covers the region every year, the main stage hydrographies and the range between high and low water vary little from

[1]埼玉大学工学部建設工学科 Dept. of Civ. and Envir. Engrg. Saitama Univ.

one year to the next. The rivers begin to rise in May or June and attains maximum level in August or September. Dry period lasts from December to April.




Irrawaddy River at Mandalay. Mekong River at Kratie.

Fig. 1. Annual Average Discharge of Selected Rivers

An examples of the annual average variation in discharge of the Irrawaddy and Mekong rivers are showed in the figure 1. These rivers were subject to tremendous fluctuation of stream flow, creating serious problems of regulation. The ratio of maximum to minimum flow on the Irrawaddy river at Mandalay, for example, is over 200, while the corresponding ratio for Chao Phraya river at Chao Phraya Dam indicated the summer maximum as much as 22 times the winter minimum. The Mekong basin river shows pronounced variations in flow, with the normal summer discharge about 21 times the winter minimum.

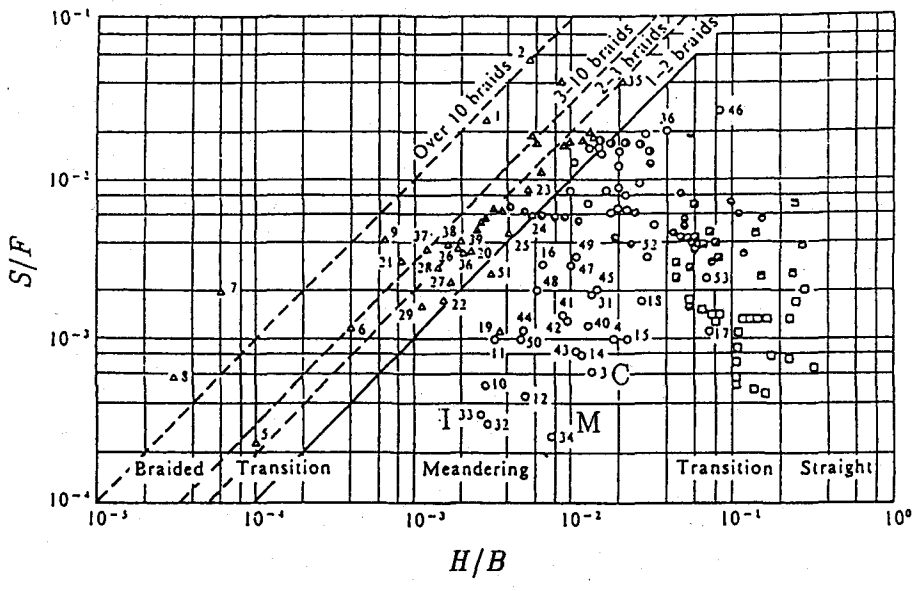



Fig.2 Parker's Straight/Meandering/Braided regime diagram.
I-Irrawaddy River, M-Mekong river, C-Chao Phraya River.

In study rivers for transportation it is also necessary to consider river morphology which is normally determined by the conditions prevailing at annual maximum or bankfull discharge. River channels posse three characteristic morphologies: straight, meandering and braided. Many theories have been developed to predict the characteristics of the fluvial morphologies: straight, meandering and braided. Parker (1976) has combined the analytical results and proposed the meander/braid/straight regime diagram (see Figure 2). Parker's diagram can be empirically used to predict the regime of the rivers from depth-width $H/B$ and slope-froude number $S/F$ ratios. Meandering occurs for $S/F \leq H/B$ and $H/B$ ratio being in the range from $6 \times 10^{-1}$ to $10^{-3}$.

The results concerning with meandering seem to be popularity among large South-East Asian rivers. Three rivers Irrawaddy, Mekong and Chao Phraya as showing in the Parker's diagram also are under meandering regime.

Meandering is caused by alternative bars, whose downstream is normally eroded. With proceeding of the erosion, the river gradually meanders. Alternative bars, therefore, are always seen in the meandering river channel.

These alternative bars form during seasons of high water level, and remain even after the water level reduces. The bed profile with the alternative bars causes the shifting of the navigational course along the channel. The shoaling can be seen at these shifting places and becomes an obstruction for navigation during dry season. It not only blocks the use of large vessels for inland navigation, but also reduces the payload of small and average operating vessels.

Therefore, flow and bed topography in these meandering rivers are important disciplines from the navigation point of view.

## 2. RIVER MORPHOLOGY

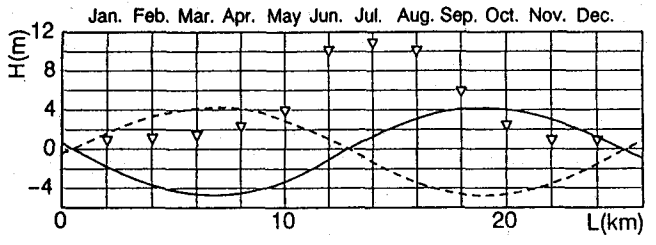
As far as transportation in concerned, the characteristic excessive length and alternating bars of a meandering river morphology are most important. Based on resent theory, the formation of meanders and their related bars heights can be predicted with some degree of accuracy which has important applications for the inland waterway transport. Ikeda and Nishimura (1986) have made the mathematical model for defining three-dimensional flow and bed topography in sinuous channels with suspendable bed material. The three-dimensional flow is separated into the depth average two-dimensional flow component and the secondary flow component. The model for bed topography is derived by considering the sediment balance for bed load and suspended load, the transport rate and direction.

For rivers under meandering regime, the bed topography in high water season can be predicted with the help of Ikeda and Nishimura's model. The input into the model are: maximum discharge, maximum average water level, width and average velocity in high water stage, average slopping, sediment characteristics and average bending radius of the channel center-line. The application of the model for selected South-East Asian rivers was carried out. The bed profiles along the downstream of the Irrawaddy river from Mandalay, Chao Phraya from Chao Phraya Dam and Mekong from Kratie were obtained in the figure 3 together with the average monthly water level.

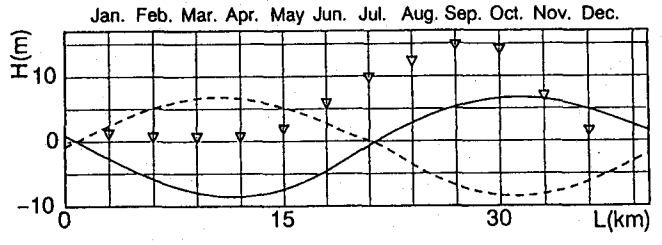
The deep pool takes place at one bank and changes to another bank corresponding to the bending direction of the channels. The optimal route from the navigation point of view can be drawn from the pool at one bank diagonally to the next pool at the other bank. The shoaling,

therefore, takes place only at the bending changed points of the channel and may become an obstruction for navigation in the low water period.

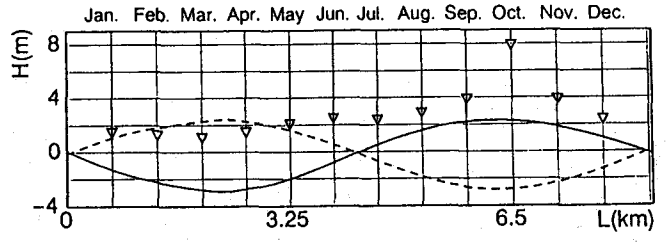
Consequently, the navigation capacity, which governed by the water level at shoaling place, could be reduced.




(a)-Irrawaddy River.




(b)-Mekong River.




(c)- Chao Phraya River.

Fig. 3. Calculated Bed Profile. (——) One Bank, (– – –) Another Bank, ∇ Monthly Average Water Levels.

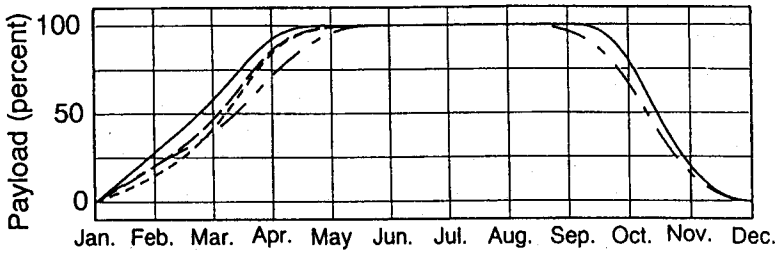
## 3. NAVIGATION CAPACITY

Owing to the shortage of water in the dry season, the draught of the vessels used for navigation was limited. As a rule the maximum draught of the vessels is greater than the depth of the water at low water so that the ships can not be fully loaded. From the water level and obtained bed profile at shoaling place, the water level available for navigation can be estimated. This level becomes critical in dry season with minimum depth at shoaling place.

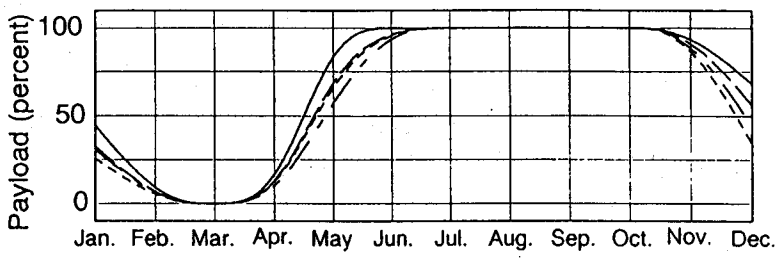
Based on the obtained bed profile, water level at shoaling place and the payload characteristics of the vessel, the limited payload of selected vessel types was predicted. The results giving by figure 4 indicated the maximum possible loading of the four typical vessel types in percentage over the year. The navigation capacity clearly reduced in the dry season along all three selected routes. The obtained results show that typically barges can be fully loaded only for 6-7 months,

for Irrawaddy river from late April to early October, for Chao Phraya river from May to December and for Mekong river from late May to November. During the period with lowest water level, which usually lasts 2-3 month, the navigation becomes critical for Irrawaddy and Mekong rivers. Along the Chao Phraya river, the barges can be operated with payload not exceeding 25 % the deadweight during the dry period from February to April. For the remaining months between the dry and wet seasons, depending on types of vessels, the payload typically varies from 25% up to 75%.

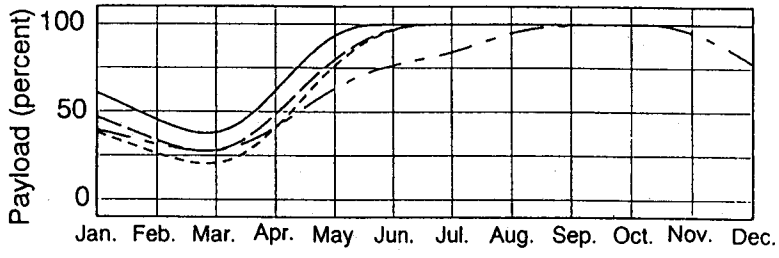
The recent theoretical predictions are based only on idealistic circumstances regarding river mechanisms and a river must be in a stable condition to allow accurate predictions.




(a)-Irrawaddy River




(b)-Mekong Rivers.




(c)-Chao Phraya River

Fig. 4. Monthly Payload of the Barge. (——) 50 Tones Barge; (– – –) 80 Tones Barge; (— — —) 300 Tones Barge; (— – — –) 700 Tones Barge.

## 4. CONCLUSION

Locating on the monsoon area, the South-East Asian rivers have two distinguished seasons in the year. The high water season normally from July to October and the low water period lasts about 3-4 months during the year. It is also necessary to consider river morphology which is normally determined by the conditions prevailing at annual maximum or bankfull discharge. Most rivers in the region have extremely low slope profiles which results in a meandering regime with the formulation an alternative bars over most of their navigable length.

The meandering could be confirmed in the regime diagram proposed by Parker and bed morphology could be predicted by the Ikeda and Nishimura's model. The results lead to the predicting the limited payload of the vessel used in these rivers over the year. The vessel payload may be significantly reduced at shoaling place during the low water season.

If such predictions can be apply, the overall efficiency and reliability navigation would be considerably improved.

## REFERENCES


Akatsuka, Y., Asaeda, T. and Brooks, J., (1994) "The Outlook for Research in Asian Inland Water Transport", Proc. 28 PIANC Congress (to appear).

Asaeda, T., Pham H. S., Akatsuka, Y. and Vu T., C., "Bed topography and Vessel's Payload. South-East Asia Case Study", Proceedings of the Inter. Conf. on Environmentally Sound Water Resources Utilization, Bangkok, Thailand, Nov. 8-11 1993.

Burma Port Corporation, "Burma Outports Project", Report on Review of Dredges 1986.

Chang, H.H., (1985) "Formation of Alternate Bars", Journal of the Hydraulic Division, ASCE, Vol.111, No.11, November, pp. 1412-1420

Ikeda, S. and Nishimura, T. (1986) "Flow and Bed Profile in Meandering Sand-Silt Rivers", Journal of the Hydraulic Division, ASCE, Vol.112, No.7, July, pp. 562-579.

Parker, G., (1976) "On the Cause and Characteristic Scales of Meandering and Braiding in Rivers", J. Fluid Mechanic, Vol. 76, part 3, pp. 457-480.

The World Bank, (1980) "Thailand Staff Appraisal Report Inland Waterways and Coastal Ports Project", Project Department East Asia and Pacific Regional Office, June 3.

UN, (1964) "Methods of Hydrological Forecasting for the Utilization of Water Resources", Economic commission for Asia and the far East, World Meteorological Organization.

UN, (1968) "Water Legislation in Asia and the Far East", Part 1 Water resources series N35.