東京の河川交通と安全性

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On the River Traffic in Tokyo and Safety Factor

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概 要

ロンドンのテムズ川，パリのセーヌ川，ニューヨークのハドソン川など多くの都市が河川と結びついているが，東京の中心部を流れる河川としては隅田川がある。

隅田川をはじめ東京周辺の河川は利根川水系を中心に古くから船舶交通が盛んで多くの旅客や貨物の輸送がなされてきた。現在，これらの水運は鉄道や道路輸送に移行しているが，唯一の例外として隅田川における船舶交通があげられる。また一方で隅田川は早慶レガッタや両国の花火，墨田公園のお花見などを通じて広く親しまれてきた。東京商船大学では学校の創立が隅田川に浮かぶ成妙丸においてということもあって，開校以来行われてきた早朝カッター訓練や学生祭前日のカッターパレードなどにより隅田川から様々なかたちで恩恵をうけてきた。このような隅田川が今後も様々な方面から有効に利用されることは望ましいことである。そのためにも隅田川の船舶交通の実態を継続的に調査し問題点を抽出しておくことが必要と思われる。

東京商船大学の航海実習教室ではこのような観点から1989年以降現在まで隅田川の船舶通航実態を調査しいくつかのテーマについてまとめてきた。本報告ではそれらの観測結果をもとに通航実態をまとめいくつかの安全通航に対する問題点を考察した。

1. INTRODUCTION

In the Edo era, about 150 years ago, ship's traffic at the River in Tokyo (Edo) was the most important traffic means. In these days railway traffic and road traffic take place of river traffic. But it remains a little at the River Sumida which is the main river in Tokyo. Authors have been observed ship's traffic of the River Sumida in Tokyo since 1989. They also observed ship's traffic of the Arakawa and the Nakagawa which flow at the east of the River Sumida. Moreover they observed ship's traffic from the mouth to the upper part of the River Sumida.

From these observations it was shown that 280 ships per day navigated the River Sumida and that the mean traffic interval was 3 minutes. It was shown also that the River Sumida connects traffically to the Arakawa and that the traffic is decreasing at the upper stream of the River Sumida.

According as the development of the waterfront that is the River City 21 along the River Sumida, the safety of ship's traffic at the river is being important issue. Authors also investigated on the ship's collision accident and safety measures of bridge for ship collision.

2. OBSERVATION RESULTS OF SHIP'S TRAFFIC

Observation of ship's traffic at the rivers in Tokyo was executed by Institute of Ship's Training and Operation, Tokyo University of Mercantile Marine. These are the research on ship's traffic at the mouth of the River

Sumida[1], the research on ship's traffic difference at the upper, middle and lower reach of the River Sumida and the research on ship's traffic at the lower reach of the Arakawa and the Nakagawa[2]. Fig.1 shows observation points of ship's traffic at the River Sumida, the Arakawa and the Nakagawa.

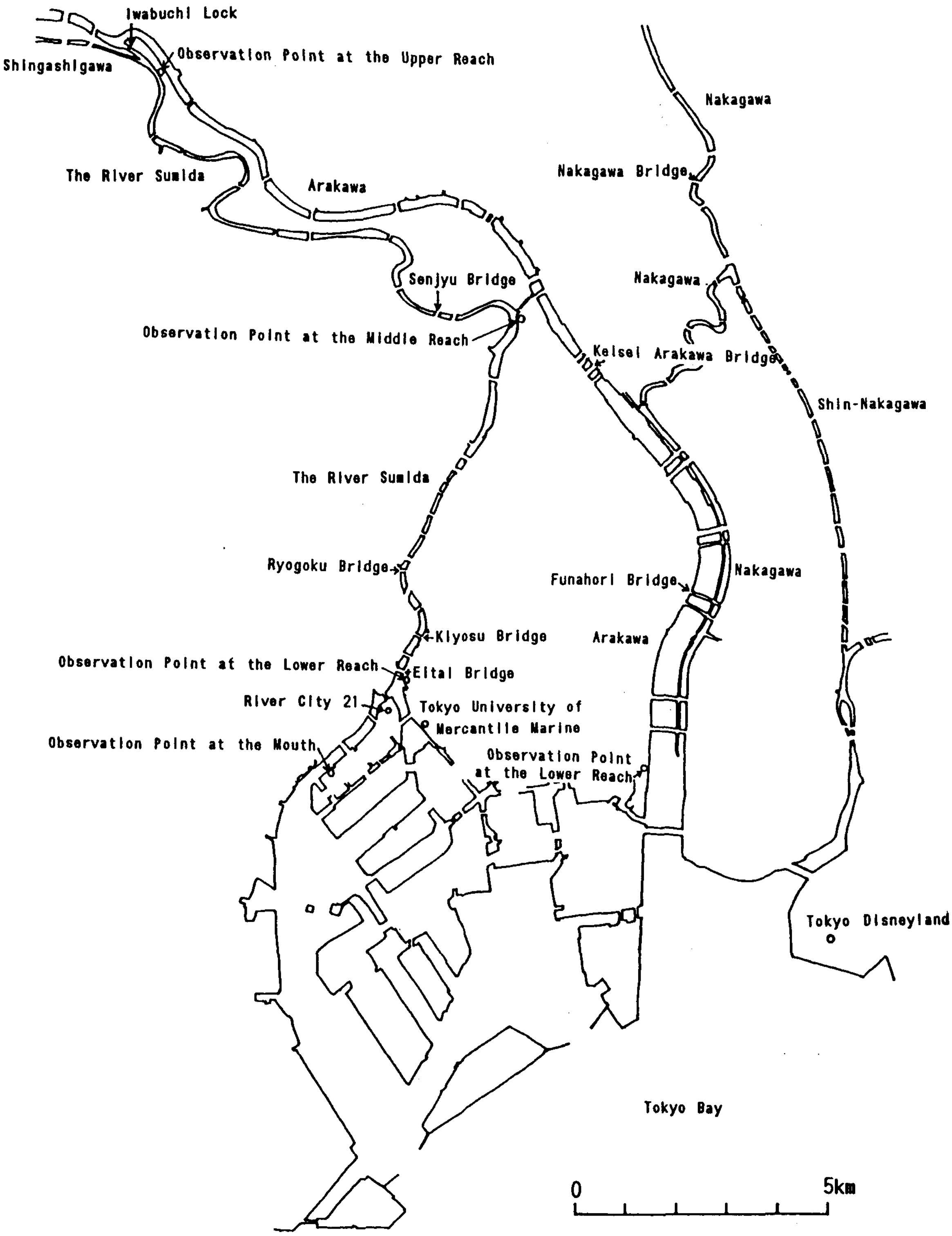


Fig.1 Observation Point of the Ship's Traffic

Observation at the mouth of the River Sumida was executed for about one year from sunrise to sunset at the date shown in Table 1. Observation items are passing time, ship's name, type of ship, direction of navigation and load condition. From this observation, ships traffic in a year is shown in Fig.2 and traffic time interval in a year in Fig.3. As the result, it was shown that mean traffic in weekdays are 276 ships per day. In these traffic, product oil carriers were 99 ships per day (35.9%), tug boats were 76 ships per day (27.4%), official boats were 27 ships per day (9.9%), leisure boats were 39 ships per day (14.2%) and others were 35 ships per day (12.6%). The percentage of upstream and downstream navigation were respectively almost 50%.

Table 1 Observation Date at the Mouth of the River Sumida

1st. :	25.10.1989	(Wednesday)
2nd. :	21.11.1989	(Tuesday)
3rd. :	20.12.1989	(Wednesday)
4th. :	18.01.1990	(Thursday)
5th. :	14.03.1990	(Wednesday)
6th. :	25.04.1990	(Wednesday)
7th. :	17.05.1990	(Thursday)
8th. :	21.06.1990	(Thursday)
9th. :	18.07.1990	(Wednesday)
10th. :	24.08.1990	(Friday)
11th. :	18.09.1990	(Tuesday)

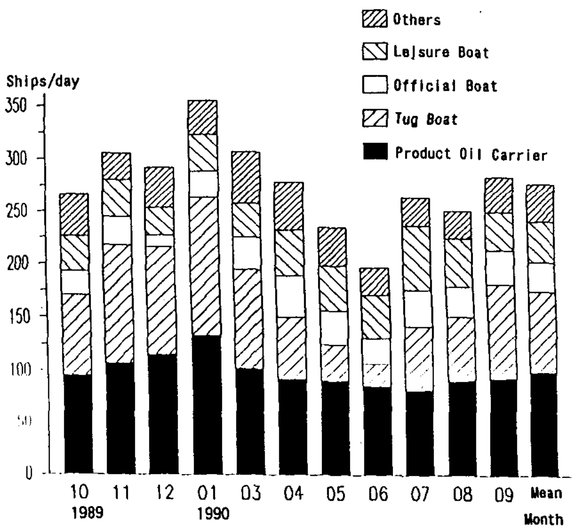


Fig.2 Ship's Traffic at the Mouth of the River Sumida

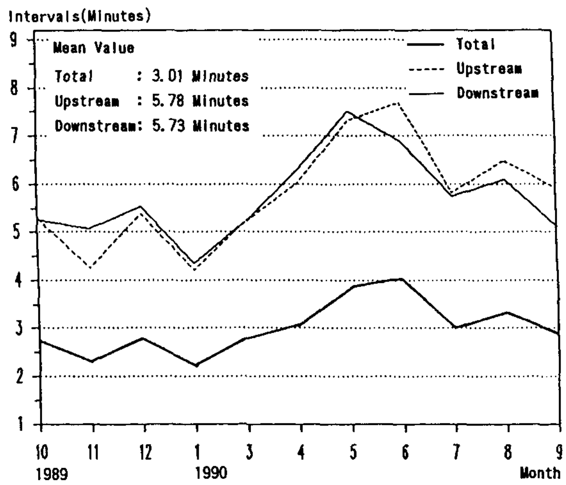
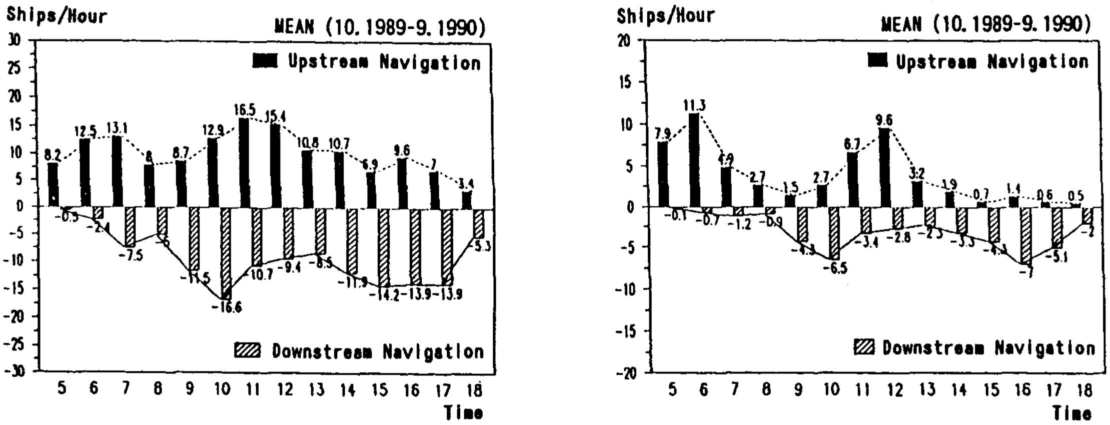


Fig.3 Traffic Intervals at the Mouth of the River Sumida

From November to January, the traffic of product oil carrier increase according to the demand of petroleum in winter season. This is the same tendency as the traffic of domestic oil carrier at the Tokyo Harbor. The traffic of tug boat increase also from November to January. This is concerned with construction season on the waterfront development. The traffic of leisure boat increase from July to September,as the reflection in summer season. From Fig.3, mean traffic interval is 3.01 second. Mean traffic interval of upstream and downstream navigation is 5.78 and 5.73 minutes respectively.

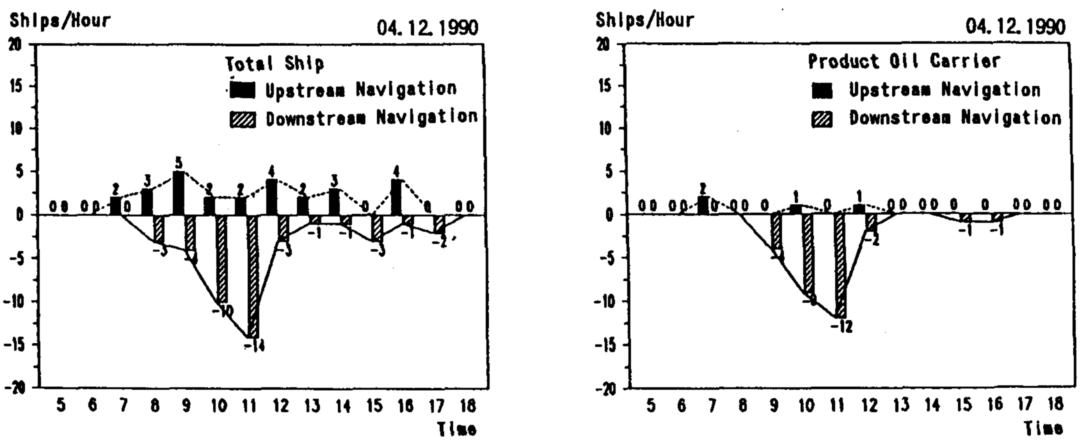
Fig.4 shows the hourly change of traffic at the mouth of River Sumida. From these observation, ship's traffic pattern has also two peak traffic hours, which are 10 A.M. and 14 P.M., which is same as the road traffic pattern of the city area. At these peak hours traffic interval is 1.8 minutes. This time interval means that the traffic is very confused. In the case of product oil carrier, one peak hour of upstream traffic appears early morning. These ships go down the river before noon. Another navigation pattern of this carrier is that the ships go up noon and go down in the evening.



(a) Total Ship (b) Product Oil Carrier

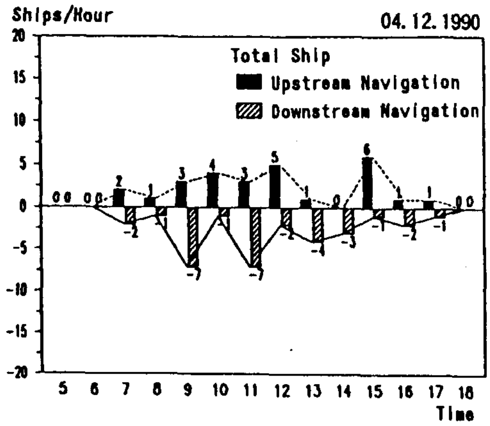
Fig.4 Hourly Change of Traffic at the Mouth of the River Sumida

Fig.5 shows hourly change of traffic at the lower reach of the Arakawa and Fig.6 shows hourly change of traffic at the lower reach of the Nakagawa. From these figures, it was shown that 69 ships per day navigated in the Arakawa and 58 ships per day navigated in the Nakagawa. These are one fourth of the traffic of the River Sumida. In case of the Nakagawa the traffic of upstream navigation is same as the traffic of downstream

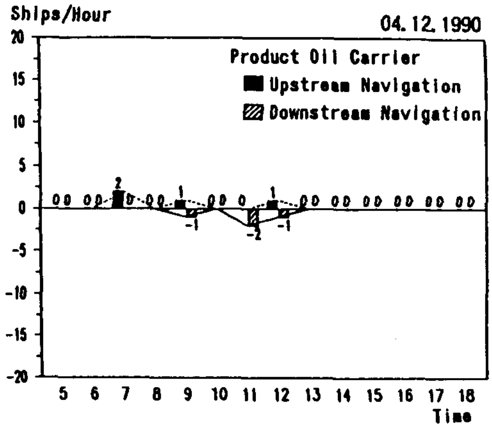


(a) Total Ship (b) Product Oil Carrier

Fig.5 Hourly Change of Traffic at the Lower Reach of the Arakawa



(a) Total Ship



(b) Product Oil Carrier

Fig.6 Hourly Change of Traffic at the Lower Reach of the Nakagawa

navigation, but in case of the Arakawa the traffic of downstream navigation is more than the traffic of upstream navigation by about 20 product oil carriers. This means that the Nakagawa is used independently, but the Arakawa is used in connection with the River Sumida. About 10 product oil carriers , which unload at the Shingashigawa, the upper reach of the Iwabuchi Lock, go up the River Sumida and go down the Arakawa passing through Iwabuchi Lock.

Fig.7 shows the change of traffic from the mouth to the upper reach of the River Sumida. From this figure, it is shown that the traffic at the middle reach is a half of that at the mouth and the traffic at the upper reach is a half of that at the middle reach. But the traffic of product oil carrier at the middle reach is almost same as the traffic at the mouth. This result shows that unload facilities of product oil is constructed at the upper part from middle reach of the river.

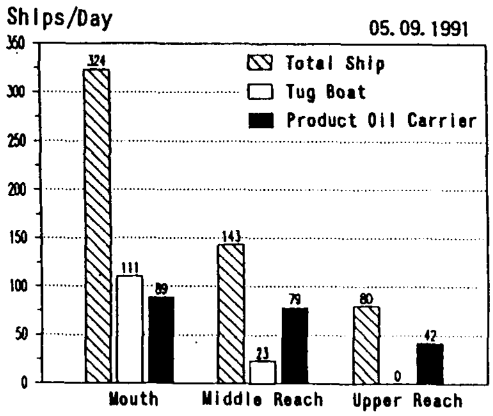


Fig.7 Hourly Change of Traffic from the Mouth to the Upper Reach of River Sumida

3. TRANSPORTATION OF PETROLEUM BY SHIP IN TOKYO

Table 2 shows the mean size of product oil carriers which navigate the River Sumida. This table shows also the example of canal going ship in Germany. Both sizes are very similar, especially on length, breadth and draft. Using this mean size carrier, transportation capacity by ship is estimated. Suppose that the mean cargo capacity is 382 m^3, loading rate is 0.95 and 50 carriers navigate meanly from the traffic observation, transportation capacity is about 18,000 m^3 per day. If the specific weight of petroleum is 0.83, transportation

Table 2 Mean Size of Product Oil Carrier

Navigation Area	The River Sumida	Canal in Germany
Type	Product Oil Carrier (mean)	General Cargo (example)
Gross Tonnage	164.4 GT	239 GT
Deadweight Tonnage		
Load Capacity	382.3 ㎥	
Length overall		42.35 m
Length (Lpp)	32.3 m	38.60 m
Breadth molded	7.3 m	7.58 m
Draft		2.41 m
Depth molded	2.6 m	

weight becomes 15,000 ton per day and this becomes 300,000 ton per month supposing that one month has 20 workdays. Consequently transportation capacity is 3,600,000 ton yearly.

It is said that 7,500,000 ton petroleum is imported in Tokyo by ship yearly and that 11,000,000 ton petroleum is imported in Tokyo by ship and automobile yearly. Therefore the product oil carrier at the River Sumida transports about 50% of imported petroleum in Tokyo by Ship or about 33% of imported petroleum in Tokyo by ship and automobile. From this result, the River Sumida forms the main artery of energy transportation in Tokyo area.

4. ANALYSIS OF SHIP COLLISION ACCIDENT

Accident data can be collected from Lloyd's Weekly Casualty Reports and so on. From this data, it is seen that the number of accident is about at least 10 per a year and is not decreased now. Table 3 shows the ship collision accident with bridge which spans the river in Tokyo. From the accident data, authors investigated about the factors of accident cause. One of these causes is the geometrical factor consisting of the waterway and bridge. That is straight way, horizontal clearance, turning angle, waterway crossing angle, vertical clearance under bridge and so on, which are shown in Fig.8 and Fig.9.

Fig.10 shows the relation between main span of bridge (S) and straight way (R)[3],[4]. From this figure, the probability of ship collision is increased in case that the main span is less than 3 times the ship length and in case that the straight way is less than 8 times the ship length. That is, main span of bridge and straight way have compensatory relation to the safety of ship collision accident. The probability of ship collision is decreased in case that main span is less than 3 times the ship length provided that straight way is more than 8 times the ship length. The probability of ship collision is decreased in case that straight way is less than

Table 3 Accident Data at the River in Tokyo

Time, Day. Month. Year	Ship's Name	Cargo	GT	Collided Bridge
0800, 21. 07. 1966	Yutaka Maru	oil	74GT	Funahori Bridge
1900, 15. 02. 1967	Hisa Maru No.3		72GT	Ryogoku Bridge
1520, 23. 03. 1978	Fukuyu Maru No.1	oil	122GT	Senjyu Bridge
1000, 26. 05. 1978	Chitose Maru No.2		66GT	Senjyu Bridge
1150, 22. 08. 1978	Kulku Maru No.7	general	182GT	Kiyosu Bridge
1045, 17. 01. 1979	Hojyu Maru No.3	oil	128GT	Senjyu Bridge
1620, 03. 09. 1986	Chosei Maru	oil		Arakawa Bridge
1000, 11. 10. 1990	Narita Maru No.5	oil	91GT	Nakagawa Bridge
0600, 05. 01. 1991	Fujimiya Maru No.8	oil	141GT	Keisei Arakawa Bridge

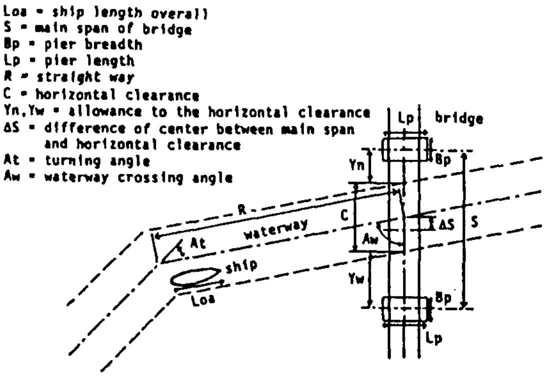


Fig.8 Diagram of Horizontal Relations between Waterway, Bridge and Ship

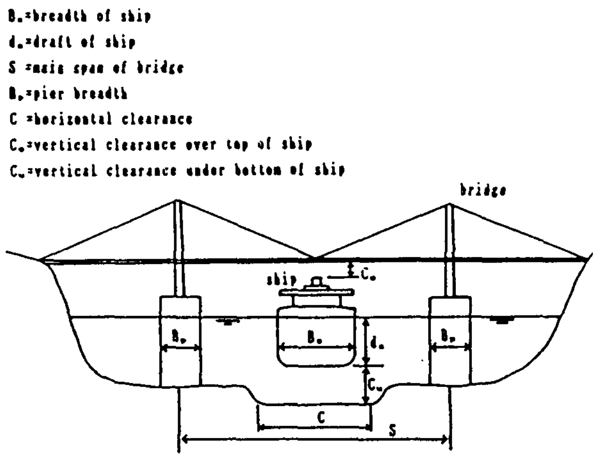


Fig.9 Diagram of Vertical Relations between Waterway, Bridge and Ship

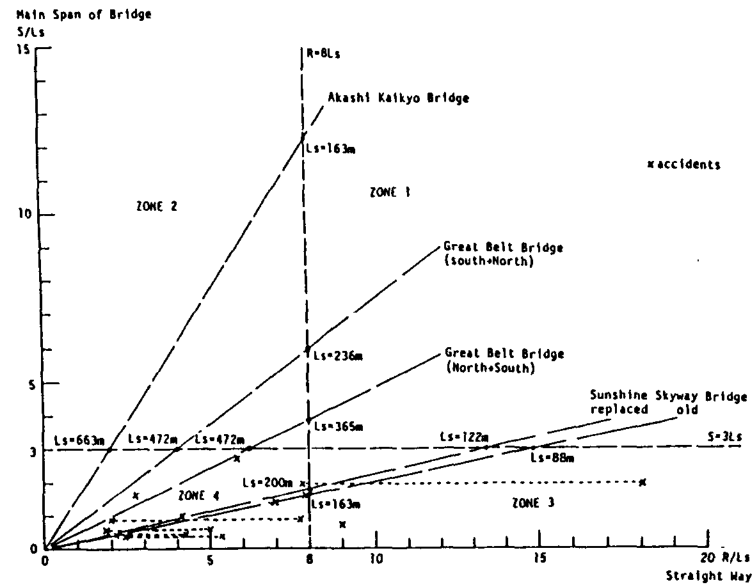


Fig.10 Main Span of Bridge and Straight Way related to Ship's Size

8 times the ship length provided that main span is more than 3 times the ship length. This result is very similar to the figuresof shipavoidance area (ship's domain) in marine traffic engineering as shown in Fig. 11.

5. SIMULATION STUDY ON CURVED CHANNEL NEAR BRIDGE

From the analysis of the accident data, it was found that the effect of curved channel is one of the most significant causes which affect the ship collision accident. Then the simulation study of the ship passing the curved channel near the bridge is executed[5].

Fig.12 shows the simulation result of the effect of turning point and turning angle. For example in order to turn to the next course, rudder operating point should be changed suitably according to the turning angle, water depth and the effect of wind or current. From the calculations based on variation of straight way, it is difficult to decide which limiting length should be taken for the safety against ship collision. If rudder operating

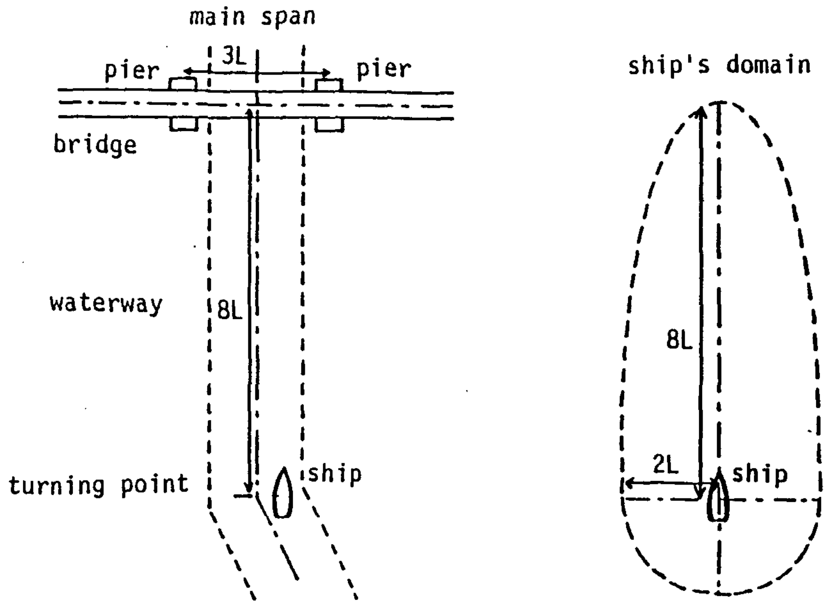
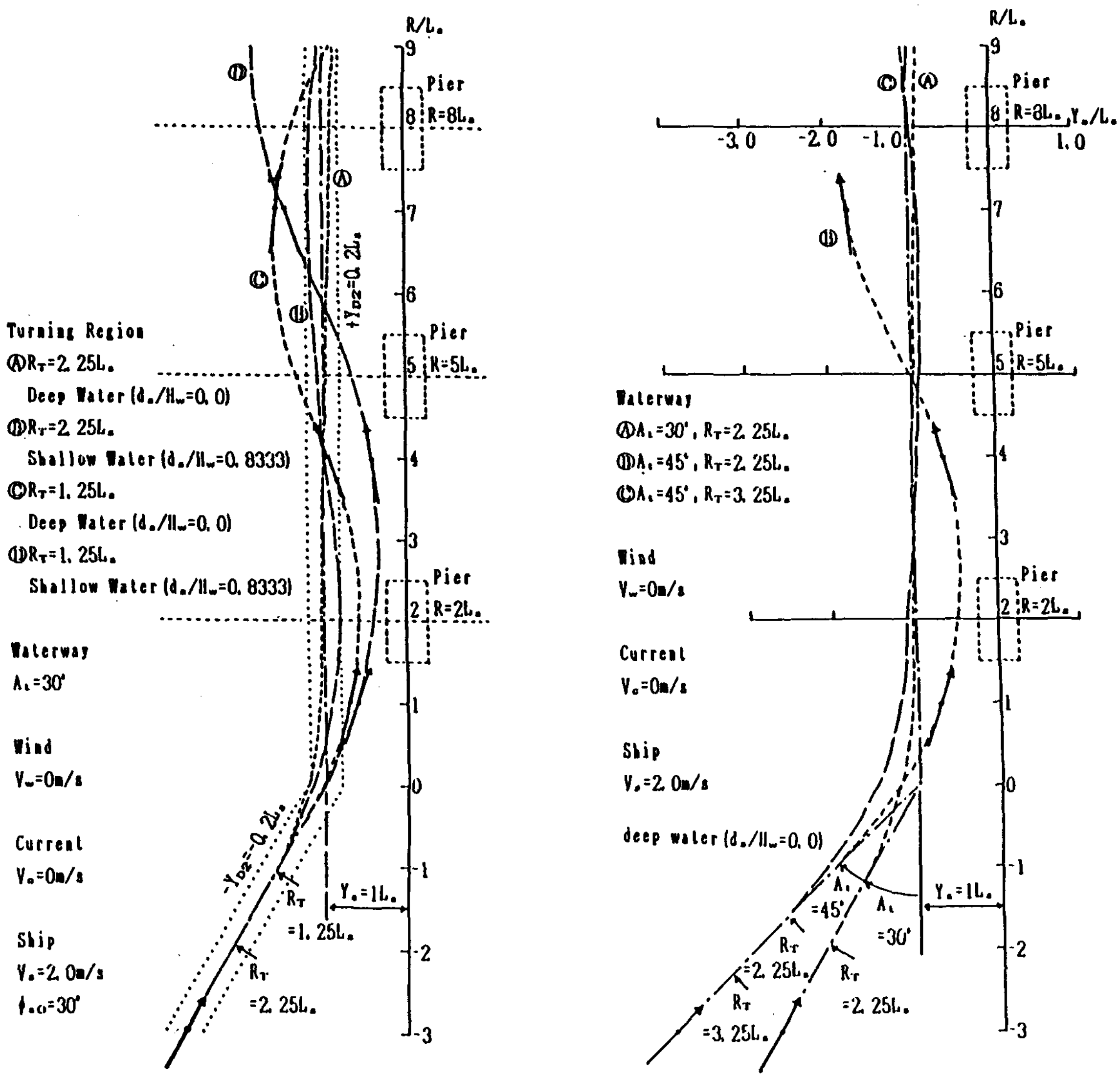


Fig.11 Waterway Passing through Bridge and Ship's Domain



(a) Effect of Turning Point (Rt)　　(b) Effect of Turning Angle (At)

Fig.12 Ship's Trajectories affected by Waterway point(Rt) is delayed by one ship length, the probability of collision with bridge increases as shown in Fig. 12. 2Ls straight way (R=2Ls) is short for ship to pass though bridge safely as shown in Fig.12.

6. CONCLUSIONS

Authors observed the ship's traffic at the river in Tokyo, researched the ship collision accident with bridge and considered the safety measures for navigation at the river in Tokyo. From these study, the importance of the River Sumida as a main artery of energy transportation in Tokyo was recognized in the first place. From the analysis of accident and simulation study, it is known that the design of bridge and waterway is important to safety against ship collision.

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