Introduction

Movable bridges are designed and constructed to change its position and occasionally its shapes to permit the passage of vessels and boats in the waterway. This type of bridge is generally cost effective since the utilization of long approaches and high piers are not required. When the waterway is opened to vessels and ships, traffics over the bridge would be stopped and vice-versa. Moveable bridge is a bridge that can change position (and even shape in some cases) to allow for passage of boats below. This has a lower cost of building because it has no high piers and long approaches but its use stops the road traffic when the bridge is open for river traffic.

The oldest know movable bridge was built in the 2nd millennium BC in the ancient Egypt. History also knows for one early movable bridge built in Chaldea in the Middle East in 6th century BC. Since then they were almost forgotten until Middle Ages when they again appeared in Europe. Leonardo da Vinci designed and built designed and built bascule bridges in 15th century. He also made designs and built models of swing and a retractable bridges. Industrial revolution allowed for new technologies like mass-produced steel and powerful machines and it is no surprise that new types of modern movable bridges appeared in 19th century. They are built even today but many movable bridges that are still in use in United States are built in early 20th century. In time, some of them are repaired with lighter materials and their gears are replaced with hydraulics.

Types of Movable Bridges

Various types of movable bridge are available, but three of them are significantly desirable and practical are discussed in the following sections and number of special types of movable bridge will be discussed as well:

- Bascule bridge
- Swing bridge
- Vertical lifting bridge
- Special types of movable bridge
➢ Bascule Bridge: Bascule bridge, which is also called as drawbridge, is fixed and supported on an axis which is perpendicular to the bridge longitudinal centerline axis. The horizontal line on which the bridge is pivoted is commonly located at the center of gravity of the bridge to create a balance between the weight of the bridge on either side of the horizontal pivotal axis. It should be known that the weight balance is not accurate and slight inaccuracies are provided based on the future utilization of the bridge, for example, if the tendency is to open the waterway, then the weight is distributed to help opening the bridge and this weight distribution is termed as counterweight heavy, but if the trend is to employ the weight for closing the bridge, then it is called heavy span.

There are two major types of bascule bridges including single leaf and double leaf bascule bridge. In addition to tripe and quadrable types which are occasionally constructed. The term leaf is used for the part of the bridge that moves and opens the waterway consequently. Bascule bridge is a suitable type of movable bridge for most situations. Not only does it structurally sound and reliable but also both construction and operation can be carried out economically.

Fig.1: Single Leaf Bascule Bridge
Advantages of Bascule Bridge

- It opens the water way for ships and vessels with considerable speed and it permits the passage of small size boats to pass through even if the passage is not opened completely.
- It is reported that, the passage of small boat through partially opened bascule bridge is safer compare with partial opening of vertical lift bridge and swing bridge, especially if the bascule bridge is double leaf.
- Whether fully or partially opened, most of bascule superstructure bridge is out of vessel reach during collision, so it would not suffer considerable damage.
- The time required to pass vessels through bascule bridge is smaller than that of vertical lifting bridge and swing bridge. This is because vessels may come closer to the partially opened bascule than partially opened swing or vertical lifting bridge.
- Both single leaf and double leaf bascule bridge provide obstacles for the cars, but single leaf provides barrier at one side of the road.
- Double leaf bascule bridge offers the broadest spaces for vessels compared with other types of movable bridges.
- The depth of the span that extended from the pier to the center of the bridge can be decreased.
Disadvantages of Bascule Bridge

- Bascule bridge is subjected to considerable wind load especially when it is opened. So, this should be accounted for during the design of bascule bridge.
- The machinery used to control bascule bridge should be crucially strong and robust compared to the case where wind load is not present.
- In the double leaf bascule bridge where the behavior of each leaf is similar to that of cantilever in carrying live loads, shear locks are provided at the location where the end of each leaf meet which normally at the center of the channel. These shear locks are likely to suffer from wearing. This is because road dirt and other detrimental material would pollute lubricant material, and heavy traffics will impose serious shocks on the locks. The shocks will be greater as the locks are getting weaker and consequently the locks would not be suitable to perform their tasks.
- The stability of double leaf bascule bridge is based on the adequate seating of leaves on their live load shoe, alignment of the leaves, and fitting the end of each leaf by their locks. Any damages of these components due to differential temperature or wearing on the aligning components will lead to improper seating of bridge, and consequently the leaves will jump up and down under traffics which is not desirable.

Vertical Lifting Bridge

It is one of the most widely constructed and used type of movable bridge. It is composed of a span commonly truss type span which is supported by towers at the end of the span or at each corner of the span. Counterweight is usually used to balance the weight of the span. Ropes, which travels over counterweight rotating sheaves fixed on towers, are utilized to connect the end of the span to the counter weight. Added to that, waterway is opened by moving the span up exactly in vertical direction.

Types of vertical lifting bridge includes double, triple and quadrable and the last two types are suitable for crowded areas such as in front of terminals. If the machinery used to open and close the water way is fixed on the span, then the bridge is called span drive vertical lift bridge, whereas the bridge is termed as tower drive vertical lift bridge if machineries applied to lift and down the lift span is fixed on towers, in addition to many other variations of vertical lift bridges. This type of bridge is considerably suitable for locations or cases where long spans are required because vertical lift bridges are substantially stable.
Fig. 3: Vertical Lifting Bridge

Fig. 4: Details of Lifting Bridges
Advantages of Vertical Lifting Bridge

- Vertical lifting angle can be built approximately with any length that is required according to the project location and it is only restricted by ultimate simple span.
- The design and construction of vertical lifting bridge is easier compared with swing and bascule bridges.
- It is suitable to support heavy load structures like railroad bridge since vertical lifting bridge spans are approximately fixed.
- There is no restriction on the width and the number of trusses or main girders of vertical lifting bridge.
- Since vertical lifting bridge does not turn around in relation with railroads, double deck vertical lifting bridge is possible to construct and upper and lower decks can be moved up or down disregard of each other. Therefore, traffic of cars or trains need not to be blocked completely during the passage of small vessels that only lower deck required to be lifted.

Disadvantages of Vertical Lifting Bridge

- The most outstanding disadvantage of vertical lifting bridge is the restricted vertical space offered for the vessel passage. However, this has rarely caused undesired events.
- The entire width navigation channel cannot be used due to hinders posed by vertical lifting bridges even when the bridge is completely opened.
- The construction of vertical lifting towers is expensive. This is because towers should be at least 18m taller than required vertical space due to machineries and rope connection and as the height of towers increase the influence of wind load increases and consequently the construction cost rockets disproportionately.
- Vertical lifting bridges does not demonstrate satisfactory aesthetic appearance.

Swing Bridge

Swing bridge is fixed on horizontal plane that turns around vertical axis to provide ways for vessels and ships to travel through the bridge. The horizontal plane is on a bearing installed on a pier which is termed as pivotal pier. When the swing bridge is closed, the end of the span should be supported by resting piers or abutments if the total length of the bridge span is not very long. Machineries used to open and close swing bridge is more complicated compared to other types of movable bridges. The end of its span should be free during opening and closing that is why retractable rollers, wedges, shoe or jacks are introduced to lift the end of swing
span. Therefore, swing bridge moves horizontally around vertical axis to provide water way and vertical movement is not involved whereas other types of movable bridges need to move vertically to provide passage spaces for vessels. One can conclude that the influence of wind force in swing bridge is less than that of bascule and vertical lifting bridge. However, the effect of wind force cannot be neglected since it can increase overturning moment significantly especially if the bridge is fixed on a bearing at its center. The swing bridge should be supported both horizontally and vertically to carry traffics and prevent overstressing. This is because bridge stabilization due to gravity is not available as in the case of bascule and vertical lifting bridges. The span of swing bridge can be either truss or plate girder which is developed in latter times. The latter is more desired to be used since it is cost effective.

Fig.5: Swing Bridge
Advantage of Swing Bridges

- Wind load on swing bridge is minimum compared with other types of movable bridges.
- Since swing span moves horizontally during opening of the bridge, the moment generated by wind force is smaller compared with other movable bridge types (bascule and vertical lifting bridge).
- Two movable spans in one moving structure can be achieved in symmetrical swing bridge. This would be greatly advantageous to manage busy water way properly.
- It is a desirable option for locations where aesthetic play significant role in the construction of movable bridge because swing bridge does not move up to open so aesthetic of the bridge would not be affected as the bridge is opened for ships to pass through.
- Sizable piers are not required to support swing bridge because it neither lift during opening nor need counterweight as it is the case in bascule and vertical lift bridge.
- It is possible to construct double deck swing bridge because it does not lift into air to open.
Disadvantages of Swing Bridge

- It requires considerable maintenance because of large number of moving elements. So, this factor would make this type of bridge undesirable option when there is shortage of labor force.
- It needs longer times to operate compared to other types of moving bridge because it has larger number of main mechanical functions to undergo during opening and closing. Therefore, longer times will be needed to open and close the water way.
- Generally, it is assumed that wind load does not affect swing bridge considerably, but this statement is not entirely true and wind load may impose noticeable effect on the bridge for example it may exert shocking load on machinery of the bridge and as result machineries might fail to operate.
- Swing bridge needs more machinery to open and close the water way compared to bascule and vertical lifting bridge.
- The construction of supporting piers at the center of the channel provide two-way marine traffic, but this makes the bridge vulnerable to bridge collision and the size of vessel that can travel though the bridge may be decreased.
- Tools or devices used to detach swing railroad bridges is considerably expensive and fragile. That is why numerous undesired events occurred due to malfunction of such devices.
Special Types of Movable Bridge

Bridges that fall into this category are rarely constructed and uncommon. The decline in the application of such movable bridges is due to some factors such as the increase of applied loads, newly developed materials and safety precautions and concerns. Retractile, pontoon retractile, pontoon swing, shear pole swing, Folding, Curling, removable spans, Submersible bridge, Tilt bridge, Transporter bridge, Jet bridge etc. are the special types of movable bridges.

Fig.7: Folding Bridge

Fig.8: Transporter Bridge
Fig.9 : Pontoon Bridge

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