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Sea Transportation of Complete Structures

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Summary

The present paper describes the planning and design procedure for sea transport of complete structures on barges from the early planning till the transport is completed. It describes the loading conditions and design procedure and gives examples of sea transport.

Introduction

In the last decades the development of heavy lift cranes, onshore as well as offshore, and flexible trailers with high capacity has lead to prefabrication of bigger and heavier constructions in the workshops for transport and installation of complete structures.

From the offshore sector sea transport of complete platform structures and topside structures is well-known, and the advantages by fabricating the complete structure onshore are obvious.

In recent years sea transport of complete structures and spans has proved to be effective and feasible also for the bridge construction.

Many heavy industries, as for example power plants, with easy or direct access to quay may consider the advantages and profit from the seaside delivery of a complete built up section when new projects are planned.

A number of cases is known in which big cranes, tanks, etc. are fabricated in a workshop with access to a quay and then loaded on a barge and transported complete to the client.

The advantages of using sea transport in such projects are:

- Higher quality by fabricating the structures in a permanent workshop.
- Shorter construction time due to better production facilities.
- Competitive prices by fabrication in a workshop with idle capacity.

Selection of construction method and the sizes of workshop-fabricated sections are determined by transport possibilities. However, the position of the structure on the barge is given by the selection of transport method from the workshop to the barge and from the barge to the site.

In the design of the structure, the loads in the sea transportation situation will in many cases give the critical load cases.

The wind and wave loadings during the transport depend on the transportation route as well as the season. For instance transport in Oeresund will give an operational wave height of

H_S < 0.5 m, whereas the significant wave height for the Halmstad region is H_S < 1.5 m, when choosing the same possibility for completion.

When choosing climatic loads reliable meteorological data and weather forecasts will determine the transport loads completely.

The sea transport and transport method must be planned at an early stage in order to make an optimum design with respect to transport loads and transport methods.

It is very important that the planning of the sea transport is included in a project from the early beginning as the sea transport might lead to some modification and/or reinforcement of a structure.

Early planning will result in a safe tansport which minimises the risk of failure, which normally means total loss of the structure. In the past large cranes have been lost from barges in the Biscaya, the North Sea and the Baltic Sea.

Planning

A clear distinction between planning, loading and design is not possible as they are strongly intertwined. This is why a sea transportation project will always be an interactive process.

The preliminary investigation is very important because apparently insignificant factors may result in large expenses and at worst the failure of the structure.

Planning of sea transports requires clarification of a number of aspects.

- Possible unloading harbours inclusive of. contact to harbour authorities.
- Possible transport routes inclusive of distress harbour
- Possible loading and unloading methods
- Onshore transport
- Verification of environments (Weather window principle)
- Choice of barge
- Verification of accelerations (Motion response analysis)
- Stability analysis
- Ballast calculations
- Preparation of operational manuals for the transport
- Meteorological assistance during the transport
- Insurance of the transport
- Approvement by Marine Warranty Surveyor
- Classification of barge in case of major modifications
- Design of sea fastening, mooring and ramps
- Stipulation of towing pull for the tugs
- Loading and towing manual
- Design basis for the construction which had to be transported
- Estimate of cost for the total transport
- Risk analysis

The size of the barge must be found and the market for barge hire must be checked at an early stage in order to find available barge dimensions in the planned period.

If the structure which had to be transported is sensible to the motions, the barge can be ballasted or it can be an advantage to chose a barge of a larger dimension than needed in order to reduce the size of acceleration.

Loading conditions

The feasibility of the project depends entirely on the weather. Therefore it is important to determine a weather window for the operation, or several in case of safe stops along the way.

A weather window is a period of time in which it is possible to predict with certainty that the loads will not exceed the conditions laid out in the design.

The weather window is determined by factors such as time of year, sea lane, possible distress habour and frequent wind/wave direction.

Cost can be reduced by planning the transport in the summer period and by choosing favorable environmental loads. However, this can lead to a critical transport in case of for instance a delay in the project. If the season of the transport is unknown, the transport loads must be based on yearly environmental loads.

The loads on a construction during sea transport is

- Dead load of the structure
- Wind load
- Splash on the structure
- Accelerations due to the barge motion in the waves

The movement of a barge can be described by the following:

Rotations	Translations
Roll (Rotation about the longitudinal axis)	Surge (Longitudinal movement)
Pitch (Rotation about the transversal axis)	Sway (Perpendicular movement)
Yaw (Rotation about the vertical axis)	Heave (Vertical movement)

As the resulting acceleration forces increase with the distance from the rotation axis it is important to place the sensitive items above the center of the barge and as low above the deck as possible. The rotation axis for each rotation is situated between the center of gravity for the barge inclusive of deck load and the center of buoyancy.

It might be noted that any elevations above the deck level due to secondary items will require heavy seafastening constructions due to the large horizontal acceleration forces.

In many cases the loading on the structure is estimated by simple formulas for the movement. In the Danish North Sea area the following motion parameter has been used.

Roll	:	amplitude 20° with a period of 10 sec.
Pitch	:	amplitude 12,5° with a period of 10 sec.
Heave	:	0,2 x g.
Loadcase	:	Roll + Heave or Pitch + Heave

It shall be noted that the above practice will lead to a conservative design.

There are no easy design rules for transportation by barge. A motion response analysis for the actual transport is necessary if a consensus knowledge of the actual loads are desired. Luckily wave data for many sea lanes are available and the analysis can be carried out by using an advanced finite element programme like GTSTRUDL.

Loads on the structure during loading and unloading inclusive of onshore transport have to be considered.

In this situation the structure will often have unfavourable support conditions compared to a permanent situation and the sea transport conditions.

In the specific situation it might be evaluated if the loads during the sea transport and land transport will have any consequences with respect to the lifetime of the structures due to fatigue.

Design

The design will typically include design of the following main items:

Onshore Transport

- Transport equipment
- Transport route
- Analysis and reinforcement of structure.

Load Out/In

- Transport equipment
- Ballast calculation
- Moring analysis
- Analysis and reinforcement of structure.

Sea transportation

- Stability analysis
- Towing
- Sea fastening of the structure
- Design of the structure.

Stability Analysis

The stability analysis is carried out on the basis of different rules published by the classification companies, for example Lloyd's rules for mobile offshore units.

These rules will not be discussed in here, but it is a fairly simple analysis which should be carried out at an early stage.

Towing

The towing analysis is primarily carried out in order to determine which tug force to use in order to uphold a given speed. The results come from the Motion Response Analysis, or alternatively experiences from former towings may be used.

Sea fastening

Sea fastening is the structure that safely ties the structure to the barge, and the design includes a local check-up of the barge.

If the standard load tables of the barge cannot be used, then a new calculation of the barge and a subsequent classification is required. This operation is very costly and should therefore be considered carefully.

Design of Structure

In the permanent situation a structure has to be designed according to the local codes with respect to loading.

For the sea transport the design loads are given on basis of a Motion Response Analysis.

For the onshore transport, loads from local codes and experience from previous transport are to be used.

The safety loads for the static as well as the fatigue analysis will however, always be according to local codes.

Onshore Transport

The choice of onshore transport from the workshop to the barge and from the barge to the site depends on the structure and the transport distance, and finally also whether it is a one time operation or repetitive operations.

In case of one-off operations over long distances, it is often favourable to use flexible selfpropelled platform trailers. The height of trailers are 1.5 m to 2 m which raises the structure above the barge deck and requires heavy seafastening.

If the distance is shorter skidding on rails can be used.

The structure can either be equipped with PTEE plates with low friction or with roller skate.

An alternative is to use aerofoil plates which require relative plane and close surfaces as smooth concrete or steel plates. The advantage is the distribution on the load over a large area which leads to a low pressure.

The critical point in the onshore transport is in all cases the pass from land to the the barge. For the last mentioned equipment the ballasting during load out is sensitive, however less critical if platform trailers are used.

If the structure is constructed in a dry dock with large crane capacity, the structure can be lifted while the dock is filled and the barge positioned below the structure.

Examples of Sea Transport

In the following three examples of sea transport will be described.

Transport of Coal Cranes

The two cranes were built in Aalborg harbor and transported 200 km to the "Coal Landing pier" by the power plant "Asnæsværket". The cranes were transported complete with the crane booms erected in horizontal positions. The height of the structure and the relatively high waves justify a thorough investigation of the transport.

For a number of elements the transportation load case was most critical and the cranes were temporarily braced. The barge was equipped with rails and the cranes were loaded on and off on their own wheels.

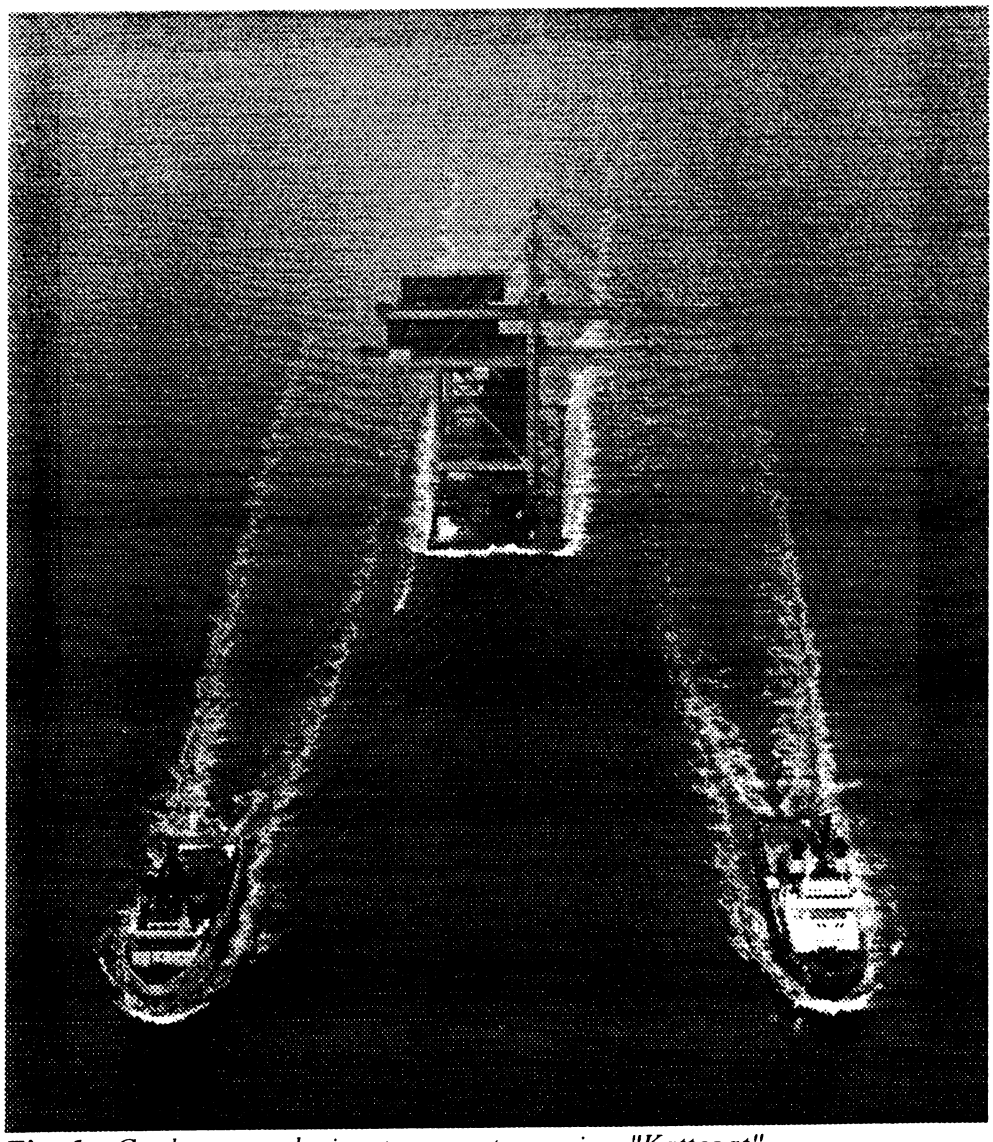

Fig. 1. Coal cranes during transport crossing "Kattegat"

Transport of Gantry Crane

The possibility of transporting a big crane with a weight of 7200 tonnes from Malmö to Copenhagen was investigated.

As the cost for dismantling and reassembling of the crane legs exceed the expenses for whole transportation of the complete crane structure, the last was chosen.

A solution with one large barge was rejected due to

- Special large barges are not normally available.
- The height of the barge compared with the water depth required elevation of the crane by 2 m above the final level.
- Expenses due to reinforcement of barge deck for installation of crane rails.

Each leg of the crane is supported by means of 2 barges with rigid connections

The connection between the legs is established by 3 barges hinged to each other, which was less expensive than purpose-made beam connections.

The solution with the hinged standard barges was possible due to the shallow water.

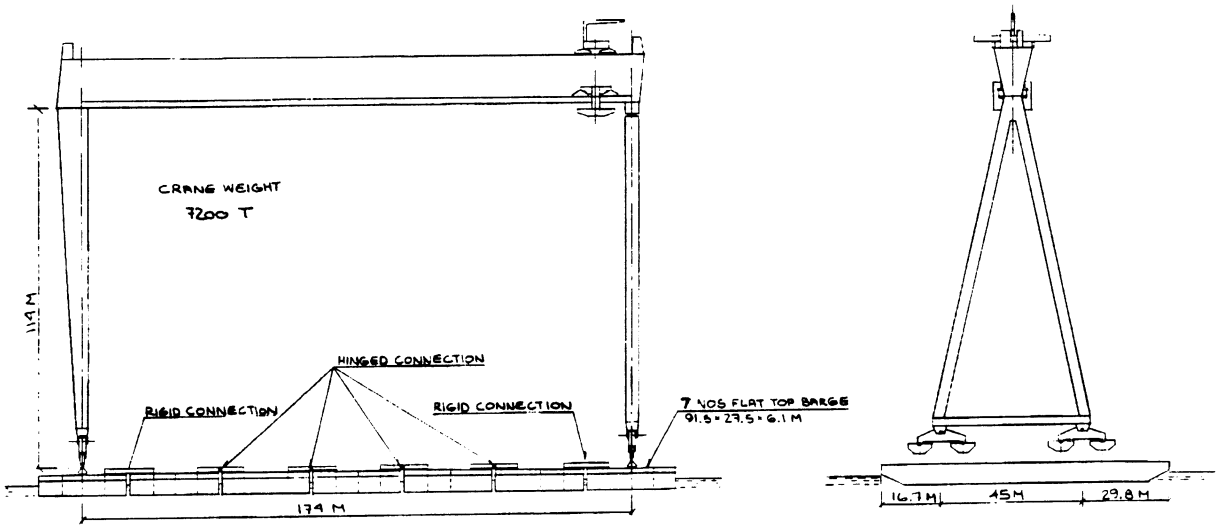

Fig. 2 . Cantry crane loaded on connected barges.

Transport of Bridge Sections

When a bridge is planned the erection method is naturally a part of the design. Bridges crossing waterways will normally be mounted from the seaside. The transport shown is one proposal for erection of the Øresund bridge. The large barge will increase the stability, but the main issue for the size is to keep a very small draft which is required due to the water depth by the coasts.

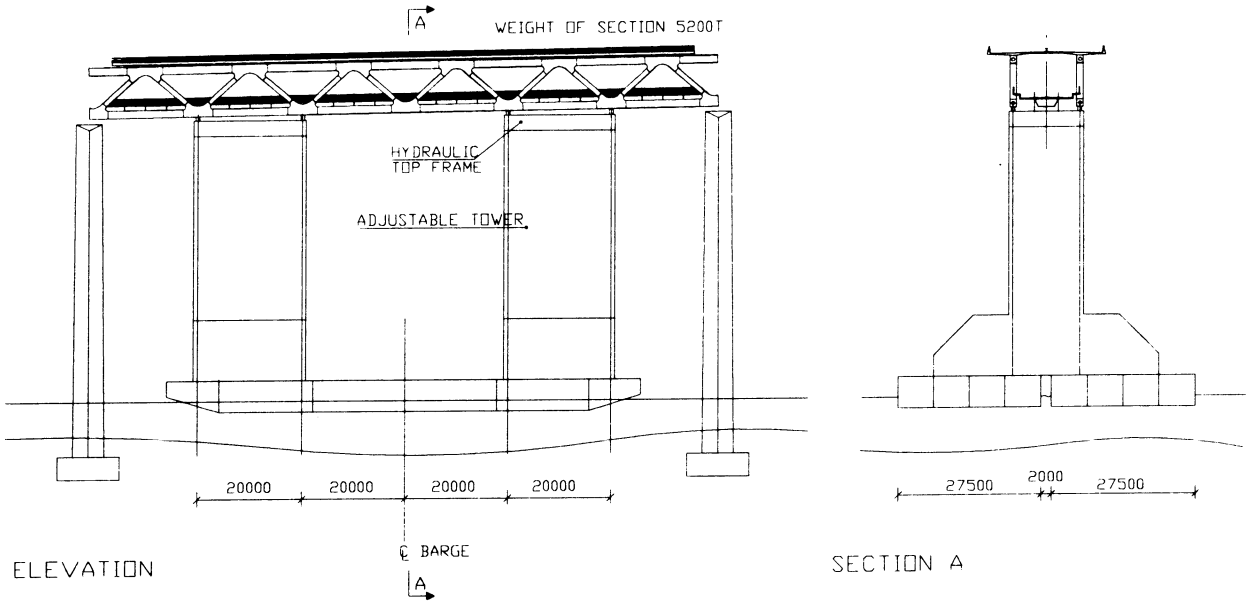

Fig. 3. *Bridge section transported in installation height.*

References

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