Advice on the beam of inland vessels and width of locks related to efficient continental container transport

van Dorsser, Cornelis; Verheij, Henk

Publication date
2016

Citation (APA)
van Dorsser, C., & Verheij, H. (2016). *Advice on the beam of inland vessels and width of locks related to efficient continental container transport*. Delft University of Technology.

Contribution to PIANC InCom WG 179

Advice on the beam of inland vessels and width of locks related to efficient continental container transport

Cornelis van Dorsser
Henk Verheij

Contribution to PIANC InCom WG 179

Advice on the beam of inland vessels and width of locks related to efficient continental container transport

Authors:

Dr. Ir. Cornelis van Dorsser
Ir. Henk Verheij

October 2016

Section of Rivers, Ports, Waterways and Dredging Engineering
Department of Hydraulic Engineering
Faculty of Civil Engineering and Geosciences,
Delft University of Technology
Stevinweg 1, 2628 CN Delft
Phone: +31 (0) 15 278 98 02
E-mail: j.c.m.vandorsser@tudelft.nl
http://www.citg.tudelft.nl

Contents

Summary

PIANC InCom WG 179 investigates *“How to deal with new ships in the CEMT ’92 classification – towards a new CEMT (ITF) classification”*. This report gives an advice to WG 179 on the demands of width of lock chambers related to continental container transport with vessels with a beam adjusted for transport of containers of 2.60 m wide.

Transport of pallet wide, high cube, 45 foot containers (that we refer to as continental containers) increases. The first continental container barge lines recently commenced on the inland waterways. The development of continental container transport imposes a challenge on the waterway system, as existing inland vessel dimensions do not seem to be very compatible with the requirements for efficient transport of continental containers. In fact, the effective loading capacity inside the holds of standard container vessels is just 35% to 59% on CEMT II to VIb waterways. The required beam for efficient transport of continental containers by inland vessels has been assessed taking into account the fact the width of these containers ranges between 2.50 m and 2.60 m. The standard “dry” continental container (with a closed box and a door opening at one end of the container) has a width of just 2.50 m. Other continental containers (such as reefers and tank containers) tend to be wider, up to 2.60 m. The changes required to the CEMT classes to comply with the transport of continental containers of 2.60 m wide are listed in Table S1, since these vessels offer a flexible solution for all types of containers.

Based on guidelines for lock dimensions that are applied in the Netherlands an advice is given for the width of lock chambers as function of the ship’s beam. The advised widths are 1.0 m more than the required beam of the ship and also included in Table S1. Thereby, it has been assumed that the ship speed and the draught of the ships will not change.

Table S1: Necessary changes to CEMT ’92 classes to fully comply with continental container transport

Class	**Containers of 2.60 m wide**	**Beam**		**Required lock chamber width**
		Present beam	**Required beam**	
CEMT II	2	6.60 m	7.30 m (to relax constraints on stability, tonnage)	8.30 m
CEMT III	2	8.20 m	8.20 m (no changes required as beam of 7.30 m is sufficient)	9.20 m*
CEMT IV	3	9.50 m	9.50 m (no changes required as beam of 9.40 m is sufficient)	10.50 m
CEMT V	4	11.40 m	12.00 m	13.00 m
CEMT VI (barges)	5	15.00 m	15.00 m (no changes required as beam of 14.90 m is sufficient)	16.00 m
	6	N/A	17.55 m	18.55 m
	7	N/A	20.20 m	21.20 m
	8	N/A	22.80 m (no changes required as beam is similar to present beam for CEMT VI push convoys)	23.80 m
CEMT VI (pushed convoys)	2 x 4	22.80 m	24.00 m	25.00 m

*Suggested increase of present width by 20 cm to improve conditions for conventional CEMT III barges. No width increase required for transport of continental containers as 8.30 m is already sufficient.

The most relevant improvements to make the system compatible with the demands of efficient transport of continental containers are an increase in the beam of the present CEMT II class to at least 7.30 m; of the present CEMT V class to 12.00 m; and of the present CEMT VI class for pushed convoys to 24.00 m. In line with the increased beam also an increase in the width of lock chambers is required for these classes.

1 Introduction

Inland waterway transport benefits from harmonised waterway dimensions. In Europe, the inland waterways are classified according to the CEMT *(Conférence Européenne des Ministres de Transport)* classification system. The dimensions of locks are related to the size of the vessels. This report gives an advice to PIANC InCom WG 179, that investigates *"How to deal with new ships in the CEMT '92 classification – towards a new CEMT (ITF) classification"*, on the width of lock chambers in relation to new demands for the beam of inland vessels due to continental containers up to 2.60 m wide.

The present situation is presented in Section 2. After that, in Section 3, the required vessel beam is discussed. In Section 4, the required vessel beam is used to determine the required width of lock chambers. Section 5 summarizes our main conclusions. It should be mentioned that the length of vessels is of course also important for efficient transport of continental containers, but this is no part of our official advice. However, the length will be dealt with in Appendix B. Furthermore, the air draught is also relevant, but height constraints are already being dealt with by others [4].

2 Present situation

The most recent version of the CEMT classification dates back to 1990 when PIANC work group no. 9 recommended an update of the system to include, amongst others, push convoys of 2, 4, and 6 barges [1]. This recommendation was adopted by CEMT and the United Nations Economic Commission for Europe (ECE) as the CEMT '92 classification, see Appendix A.

For the present CEMT classes, the maximum beam of the barges and corresponding width and sill depth of the locks are reported in the Dutch Waterway Guidelines 2011 and the Supplement on this document [3, 11]. The values indicated in the guideline are listed in Table 1.

Table 1: Required width and sill depth of a lock chamber for a minimum capacity lock

CEMT fairway class	Beam of barge [m]	Lock chamber width [m]	Sill depth [m]
I	5.05	6.0	3.1
II	6.60	7.5	3.2
III	8.20	9.0	3.3
IV	9.50	10.5	3.7
Va / Vb	11.40	12.5	4.2 / 4.7
VIa / VIb	22.80*	23.8	5.0

Note: *Beam indicated for push barge convoys, for motor vessels CEMT indicates a beam of 15.00 m.

Nowadays, new developments once again require an update of the system [2, 3, 4, 5, 6]. Van Dorsser [5, 6] identified a clear potential for the development of continental container cargo transport over the next few decades, which are in particular shipped in pallet wide, high cube, 45 foot containers that we refer to as continental containers. However, for continental containers the required barge dimensions are incompatible with the CEMT '92 dimensions. The effective loading capacity for continental containers is in fact only 35% to 59% on standard Class II to VIb waterways, see Table 2.

Aligning the CEMT classification with the demands for efficient transport of continental 45 foot containers is obviously desirable from the commercial perspective. But it is also desirable from a broader European transport and climate policy perspective to enhance modal split and reduce carbon emissions [9, 10]. Aligning the classes requires changes to the maximum allowable beam of the vessels. This affects the required width of lock chambers. The sill depth will be unchanged, as it is assumed that the maximum draught of the vessels will not change. In general the draught will be less for continental containers, because they tend to have a lighter per volume weight and freight imbalances are also larger for continental freight flows, resulting in a lower average vessel draught for continental container barges.

Table 2: Loading efficiency of CEMT motor vessels for continental 45 foot containers

Item \ Waterway	Class II	Class III	Class IV	Class V	Class VI Rhine length	Class VI unconstrained
Maximum dimensions						
- Length	55.0 m	80.0 m	85.0 m	110.0 m	135.0 m	140.0 m
- Beam	6.60 m	8.20 m	9.50 m	11.45 m[(1)]	15.00 m	15.00 m
Hold dimensions						
- Length[(2)]	39.0 m	56.0 m	61.0 m	86.0 m	106.0 m	111.0 m
- Width[(3)]	5.25 m	6.85 m	8.15 m	10.10 m	13.40 m	13.40 m
Theoretical capacity						
- 45' cont. in length[(4)]	2.81 box	4.04 box	4.40 box	6.20 box	7.64 box	8.00 box
- 45' cont. in width[(5)]	2.01 box	2.62 box	3.12 box	3.87 box	5.13 box	5.13 box
- 45' cont. in height[(6)]	2 layers	2 layers	3 layers	4 layers	5 layers	5 layers
Total Capacity	11.30 box	21.17 box	41.21 box	95.98 box	195.97 box	205.2 box
Guaranteed capacity						
- 45' cont. in length	2	4	4	6	7	8
- 45' cont. in width	2	2	3	3	5	5
- 45' cont. in height	1	1	2	3	3	3
Actual capacity	4	8	24	54	105	120
Loading efficiency	*35%*	*38%*	*58%*	*56%*	*54%*	*59%*

Note: [(1)] Beam of 11.45 m used instead of 11.40 to reflect today's newbuilding practice; [(2)] Measured from existing vessels, Class VI based on length of hold for existing 135 m vessel plus 5 m; [(3)] Based on beam minus 1.35 m for Class I to V vessels and beam minus 1.60 m for Class VI motor vessels (as discussed in Section 3); [(4)] Based on a 13.72 m long container plus 15 cm free spacing; [(5)] based on a 2.56 m wide container plus 5 cm free spacing; [(6)] based on rule of thumb assumption that containers can be loaded as high as they can be loaded wide.
Source: Adopted from Van Dorsser [6] with data on Class VI motor vessels added.

3 Required vessel beam

The loading capacity of container vessels increases in discrete steps that go with the length and width of the containers. This section derives the required beam of the vessels from the required space for efficient loading of continental containers in the ship's hold.

The required beam for container vessels follows from: (1) the width of the containers and the required free space at each side of the container; (2) the minimum width of the side decks and plating, as set by the classification rules; (3) some extra width for the strength of the hull construction; and (4) a few other considerations such as those related to the tonnage, air draught, and stability of the barge. This section starts with a discussion on the width of the continental container, the required spacing, and the width of the side decks and plating. The required beam is defined thereafter by adding up the requirements for the first three components and taking into account the other considerations.

The width of the continental container

The dimensions of the standard 2.44 m wide ISO deepsea container were defined according to the largest permitted dimensions of the trucks that were allowed on the roads in the U.S. by the time Malcom MacLean invented container shipping in the 1950s. But these dimensions have never fitted the European freight system well, as the European freight system is pervasively developed around the pallet, that is 1.2 m wide. To enable the effective loading of two pallets next to each other the European freight system adopted wider, so called pallet wide containers, as well as longer 45 foot containers. In addition higher, so called high cube containers, were introduced globally. High cube containers are now gradually starting to dominate the international container fleet. Moreover, in 2014 for the first time in history 40-foot high cube containers accounted for the majority of boxes in service, measured in TEU [12].

The European freight system adopted the continental pallet wide, high cube, 45 foot container (that we refer to as the continental container) which has now become the new standard for continental container transport on the European continent. The continental container is attractive to shippers because it is compatible with the efficient loading of European pallets and has similar inner dimensions as a European lorry truck.

The most common "dry" continental containers (with a closed box and a door opening at one end of the container), used to be about 2.55 m wide, but more advanced production methods have reduced the width to just 2.50 m (inner dimensions are 2.44 m). Other types of continental containers, such as refrigerated containers and containers with curtains, are wider, ranging from 2.50 m to 2.60 m. The latter also holds for tank containers that have various sizes up to 2.60 m. In addition bulk containers of up to 2.55 m wide are often bulging, which implies that they require a few centimetre extra space in practice. So in general, European continental containers tend to have a width of 2.50 m to 2.60 m.

Continental container vessels need to be wide enough to handle at least the more common type of 2.50 m wide "dry" containers, but ideally the width of the vessels should be sufficient to handle 2.60 m wide containers, as such vessels offer a flexible solution for all types of containers.

The required free spacing

When container transport was introduced on the Rhine (in the 1970's and 1980's) the holds of the larger Rhine vessels (of 110 m x 11.40 m) were just sufficient to load up to 4 rows of 2.44 m wide ISO deepsea containers next to each other (Initially many Rhine vessels had wider side decks, which allowed them to load only three rows of containers). Vessels of 11.40 m beam that were built dedicated for transport of containers had a 10.00 m wide hold which has been confirmed by a few barge operators. This implies that the free spacing at each side of the container was about 4.8 cm. This spacing was considered to be sufficient but not necessarily optimal.

When the cargo load inside the container is not well balanced (i.e. the container is hanging at a certain angle in the crane) or when the ship has a certain heeling angle during the loading process, more free space is required. To improve loading operations and allow for the loading of wider containers the maximum permitted beam on, in particular the German Class Va waterways, as indicated in the German Binnenschifffahrtsstraßen-Ordnung, increased from 11.40 to 11.45 m. In addition the Rhine police regulations also set a maximum width of 11.45 for the smaller locks at Ottmarsheim, Fessenheim, Vogelgrün, Marckolsheim, Rheinau, Gerstheim and Straatsburg. In the Netherlands some width restrictions are set at 11.45 m at the Lekkanaal, the Hartelkanaal, the Naviduct Krabbersgat, and the Pannerdensch kanaal. In Belgium some waterways allow for barges of 11.50 while other waterways are still restricted to barges with a beam of 11.40 m. The IVR database [13] reports 123 dry bulk and container vessels with a beam of 11.40 m compared to 383 vessels with a beam of 11.45 m.

The hold of 11.45 m beam vessels is not just 5 cm wider than the former ones, but 10 cm, because the regulations made it possible to reduce the width of the side decks below the prescribed 60 cm over short distances at the location of bollards, see article 11.04 in Directive 2006/87/EC for present guidelines [14]. The hold of a modern Class V container barge with a beam of 11.45 m is therefore 10.10 m wide as was confirmed by a number of barge operators and owners of 11.45 m beam barges, though occasionally the width of the hold is up to 3 or 4 centimetre wider, for instance when high tensile steel is used to reduce the thickness of the plating. When loading standard deepsea containers the free space at each side of the container is now 6.8 cm, which is understood to be rather optimal from conversations with barge owners.

In addition, some barge owners indicated that it is possible to reduce the free space to just 2 cm, as they are able to load four 2.50 m wide containers next to each other in their 10.10 m holds under ideal loading conditions (no wind, no heeling of barge, proper loading of container, no bulge effect of container), albeit at cost of a fairly reduced loading speed and more frequent occurrence of damage. But they also indicated that 2 cm is not enough for reliable operations, as loading of four 2.50 m wide containers next to each other is not always possible (in some cases the containers get stuck when loading them into the hold). In addition it was understood from a Neokemp captain that smaller vessels require more free space because they encounter higher heeling angles during loading operations.

Based on the above it can be concluded that for normal loading operations of a barge that is dimensioned to load 2.60 m wide containers, it is sufficient to use a free space of 5 cm. Using a larger free space is not recommended because this would result in too much free space when loading other types of containers. The use of a free space smaller than 5 cm is also not considered ideal as this could constrain the efficient loading of, in particular 2.60 m wide tank containers, that are susceptible to damage.

The required width of the side decks and plating

Classification societies prescribe the side decks to be 60 cm wide. This implies that the beam of the barge is at least equal to the width of the hold plus 1.20 m for the side decks plus the thickness of the plating for the side walls of the hold and the hull. As 11.45 m wide container vessels are optimised for maximum width of the hold, the required width for the side decks and side plating is equal to 1.35 m (11.45 – 10.10 m). This minimum width of 1.35 m is assumed to be similar for all Class II to VIa vessels, as similar regulations for the width of the side decks are applicable to all vessels, however not taking into account the fact that smaller barges will have a slightly reduced thickness of the hull plating, which could reduce the overall width by a few cm.

For larger vessels the side decks tend to be wider than the 60 cm prescribed by the regulations, but without a more in depth study it is not possible to state precisely the reasons why vessels are constructed with wider side decks. Obvious reasons are: an increase in carrying capacity, ballast capacity and stability; but it is also possible that extra width is added to strengthen the hull construction in order to withstand, in particular, torsion forces that are imposed by adverse loading conditions. In that respect wider side decks can also be expected to reduce the lightweight of the vessel and improve the loading capacity. To take these extra considerations into account we looked at the dimensions of three real vessels with a length of 135 m. These vessels are: the Novum (135 m x 14.25 m), the Nova Zembla (135 m x 15.00 m), and the Adio (135 m x 17.10 m). The holds of these vessels were understood to be 12.50 m, 13.10 m, and 15.50 m wide. The corresponding width of side decks and plating is therefore 1.75 m, 1.90 m, and 1.60 m. It is interesting that the smallest width applies to the widest vessel. If 1.60 m is sufficient to withstand the torsion forces on the hull construction of the vessel with the largest beam, it can also be expected to be sufficient for the smaller vessels. We therefore assumed a minimum width of 1.60 m for side decks and plating of all vessels over four containers wide.

To conclude, the width of the side decks and plating is assumed to be 1.35 m for vessels with a loading capacity up to four containers wide, and 1.60 m for wider vessels.

The required beam for continental container vessels

The required beam for continental container vessels can be derived by adding up the required width for each of the individual components. The calculation of the beam is reported in Table 3.

Table 3: Required beam for 2.60m wide containers to provide sufficient space in the holds

Containers wide	Width of containers	Free Spacing	Side decks & plating	Required beam
2	2 x 2.60 m	3 x 0.05 + 0.10 m*	1.35 m	6.80 m
3	3 x 2.60 m	4 x 0.05 + 0.05 m*	1.35 m	9.40 m
4	4 x 2.60 m	5 x 0.05 m	1.35 m	12.00 m
5	5 x 2.60 m	6 x 0.05 m	1.60 m	14.90 m
6	6 x 2.60 m	7 x 0.05 m	1.60 m	17.55 m
7	7 x 2.60 m	8 x 0.05 m	1.60 m	20.20 m
8	8 x 2.60 m	9 x 0.05 m – 0.05 m**	1.60 m	22.80 m

*An additional 0.10 m and 0.05 m free spacing was added for the smallest barge types (of only 2 and 3 containers wide) to deal with the issue that for these vessels some additional beam is required to counter the effect of the higher heeling angle on the loading operations. **For the widest vessels we suggest to slightly reduce the free space between containers to comply with the present CEMT VI classes for 2 wide push convoys.

Vessels that are able to load containers up to 7 or 8 containers wide have not yet been constructed, but a recent study on *"Inland Ships for Efficient Transport Chains"* of Hekkenberg [15] clearly indicates the cost saving potential for wider vessels with a beam of up to 25 m. Plans for the development of vessels with a beam of 20 m have already been reported by professor Müller in 2003 [16].

Other considerations on the beam for continental container vessels

In addition to the required floor space, increasing the beam has also a positive effect on:

1. The carrying capacity in tonnes, which is however most important for heavy 20 foot containers and less important for the relatively lighter continental containers.
2. The air draught, that can be reduced by increasing the ballast capacity, that increases with the size of the side wing tanks underneath the side decks.
3. The stability of the barge, that is in particular an issue for the smaller Class II container vessels and increases substantially with the beam, as an increase in vessel beam directly results in an increase of the maximum loading height for the cargo, allowing containers to be stacked higher.

Taking these considerations into account we advise to apply the following requirements for the beam of continental container vessels, as indicated in Table 4.

Table 4: Necessary changes to comply with requirements of continental 2.60 m wide container transport

Class	Number of Containers	Present beam	Required beam	Remarks on required vessel beam
CEMT II	2	6.60 m	7.30 m	Need to increase beam to 6.80 m, but it is advised to increase beam to 7.30 m to relax constraints on stability, tonnage, and air draft of vessels.
CEMT III	2	8.20 m	7.30 m	No changes required: 8.20 m is sufficient.
CEMT IV	3	9.50 m	9.40 m	No changes required: 9.50 m is sufficient.
CEMT V	4	11.40 m	12.00 m	Need to increase beam to 12.00 m.
CEMT VIb (barges)	5	15.00 m	14.90 m	No changes required: 15.00 m is sufficient
	6	N/A	17.55 m	No changes required: beam smaller than 2 wide push convoys.
	7	N/A	20.20 m	No changes required: beam smaller than 2 wide push convoys.
	8	N/A	22.80 m	No changes required: 22.80 m is similar to beam already in place for 2 wide pushed convoys.
CEMT VIb (pushed convoy)	2 x 4	22.80 m	24.00 m	Need to increase to 24.00 m

The present 6.60 m beam of Class II vessels offer sufficient floor space to load two rows of 2.50 m wide “dry” continental containers, but need to be increased to 6.80 m to enable loading of all sorts of continental containers up to 2.60 m wide. However, in particular for these smaller vessels, the stability and air draught should also be considered as major constraints, that can be relaxed by a further increasing in the allowed beam. In this respect we advise to increase the allowed beam to 7.30 m.

The width of the present Class III and IV vessels is sufficient for the loading of pallet wide containers up to 2.60 m wide.

For the efficient transport of continental containers up to 2.60 m wide an increase in the allowed beam on Class V vessels up to 12.0 m is required. Modern Class Va vessels with a beam of 11.45 m can load four 2.50 m wide continental “dry” containers during optimal loading conditions, but in general the loading of these containers remains problematic. For existing locks we therefore advise to increase the allowed beam to 11.60 m if possible. Such a relatively small increase in allowed width should at least be possible on some waterways as the PIANC 1990 report already foresees in the use of vessels with a beam of 11.50 m to 11.60 m wide, for which they advised to increase the width of the locks from 12.0 m to 12.5 m [1]. In addition it may be possible to increase the allowed width at the smaller 12.0 m locks by setting a lower draft restriction for these vessels to avoid an increase in the return flow.

CEMT VIb waterways allow motor vessels to have a beam of 15.00 m, which is optimal for the transport of 2.60 m wide continental containers (we estimated that a beam of 14.90 m is required). No changes to this class are therefore required. New CEMT VIb sub-classes may be added for larger single motor vessels. For these vessels a beam of 17.55 m, 20.20 m, and 22.80 m would be sufficient, of which the size of the largest barge is similar to the present size of a two wide push barge combination.

By applying the same logic one can also advice on the required width of the holds for containers shipped in push barge combinations. At least 24.00 m would be required, enabling the use of push barge combinations with two 12.00 m beam vessels next to each other.

4 Width of lock chambers

The Dutch Waterway Guidelines 2011 [3] and the additional Supplement Guidelines [11] present a table with minimum widths for a minimum capacity lock, which is defined as a lock that can take a single reference vessel at a time (see Table 1 in Section 1). This section determines the required widths of lock chambers for inland vessels that are optimised for transporting continental containers of 2.60 m wide.

The dimensions of a lock chamber will be selected as small as possible because of the construction costs. However, a larger lock entrance makes it possible to enter and to exit the lock quicker and smoother. In general, and based on experience, a sufficiently smooth and quick enter and exit is guaranteed if the ship-lock ratio (more precise: the ratio of the underwater cross-section of the ship to that of the lock) is no more than 0.75. In formula:

$$S - L\ ratio = \frac{A_{ship}}{A_{lock}} = \frac{B_s T_s}{wh}$$

Where B_s is the ships beam, T_s the ships maximum draught, w the lock chamber width and h the water depth above the sill at the gates.

Applying this formula means that we implicitly assume that the ship speed when entering or exiting a lock will not change, and consequently also that the induced return current will not change. Higher speeds will require wider and deeper locks.

For all CEMT classes the ratio is determined and presented in Table 5.

Table 5: Lock width and sill depth for a minimum capacity lock

CEMT fairway class	Beam reference Vessel B_s [m]	Maximum draught T_s [m]	Lock chamber width w [m]	Sill depth h [m]	Ratio ship – lock [-]
I	5.05	2.50	6.00	3.10	0.68
II	6.60	2.60	7.50	3.20	0.72
III	8.20	2.70	9.00	3.30	0.75
IV	9.50	3.00	10.50	3.70	0.73
Va / Vb	11.40	3.50	12.50	4.20 / 4.70	0.76 / 0.68
VIa / VIb	22.80*	4.00	23.80	5.00	0.77

Note: *Beam indicated for push barge convoys, for motor vessels CEMT indicates a beam of 15.00 m.

Table 5 shows that the ship-lock ratio is about 0.75 except for CEMT I and CEMT II vessels. Another figure that can be deduced from the table is the difference between the ships beam and the lock width. For the Classes IV and higher the lock width is 1.00 to 1.10 m more than the ships beam; and overall the range varies between 0.80 and 1.10 m. These results can be used to come up with a recommendation for lock chamber width for new vessel types.

Based on the above the required lock chamber width and sill depth for vessels that are optimized for efficient loading of 2.60 m wide containers (as defined in Section 3) are therefore determined taking into account that:

1. The sill depth does not change as the maximum draught does not change;
2. The lock chamber width will be 1.00 m larger than the required ships beam;
3. The ship speed will be the same when entering and exiting the lock.

A 1.00 m wider lock as applied in aspect 2 is considered optimal, although ships are now better controllable due to the installed bow thrusters. Regarding aspect 3 it should be mentioned that ships are equipped with installed engines with a higher maximum power than at the time of the classifications. Thus, higher speeds are possible but as mentioned before not desirable.

Taking these considerations on the required ship's beam and corresponding lock chamber width into account, the necessary changes to make the CEMT '92 classes compatible with the demands for the efficient transport of continental containers have been defined. These are indicated in Table 6 and computed as: $w = B_s + 1.00$ m where w is the width of the lock chamber and B_s the ship's beam.

Table 6: Necessary changes lock width to comply with continental container transport

Class	Number of Containers	Required or present beam	Required width of lock chamber	Remarks on width of lock chamber
CEMT II	2	7.30 m	8.30 m	Increase with 0.80 m compared to present 7.50 m
CEMT III	2	8.20 m	9.20 m*	Increase with 0.20 m compared to present 9.00 m
CEMT IV	3	9.50 m	10.50 m	No changes
CEMT V	4	12.00 m	13.00 m	Increase with 0.50 m compared to present 12.50 m
CEMT VIb	5	15.00 m	16.00 m	New, lock width has not yet been indicated for CEMT VIb waterways
	6	17.55 m	18.55 m	New
	7	20.20 m	20.20 m	New
	8	22.80 m	23.80 m	No changes, fits within dimensions of present CEMT VIb waterways for push convoys.
CEMT VIb (pushed convoy)	2 x 4	24.00 m	25.00 m	Increase with 1.20 m compared to present 23.80 m

*Suggested increase of present width by 20 cm to improve conditions for conventional CEMT III barges. No width increase required for transport of continental containers as 8.30 m is already sufficient.

5 Conclusions

A clear potential for the development of continental container transport on the inland waterways has been identified, but the development of continental container barge lines still imposes a challenge to the inland waterway system, as the existing dimensions for inland vessels are not very compatible with the requirements for the efficient transport of continental pallet wide, high cube, 45 foot containers.

The most relevant improvements to make the system compatible with the demands of efficient transport continental containers are an increase in the beam of the CEMT II to 7.30 m; an increase in the beam of the present CEMT V to 12.00 m; and an increase in the beam of the present CEMT VIb pushed convoys to 24.00 m. Based on the required beam for a particular class the width of the lock chambers follows by adding 1.00 m to the required beam.

References

[1] PIANC (1990) *Standardization of Inland Waterway's Dimensions*, Report of Working Group 9 of the Permanent Technical Committee I, Supplement to Bulletin No. 71, General Secretariat of PIANC, Brussels.
[2] Roelse (2002) *Classificatie en kenmerken van de Europese vloot en de actieve vloot in Nederland*, Rijkswaterstaat, Adviesdienst Verkeer en Vervoer, Rotterdam, The Netherlands.
[3] Rijkswaterstaat (2011) *Waterway Guidelines 2011*, English translation of Dutch Version, Rijkswaterstaat, Centre for Transport and Navigation, Brolsma J.U. and K. Roelse (eds.), ISBN 9789036900690.
[4] Brolsma, J.U. (2014) *Rapportage containerhoogtemetingen*, DVS Rijkswaterstaat.
[5] Van Dorsser, C. (2015) *Very Long Term Development of the Dutch Inland Waterway Transport System: Policy Analysis, Transport Projections, Shipping Scenarios, and a new perspective on Economic Growth and Future Discounting*, T2015/8, May 2015, TRAIL Thesis Series, the Netherlands
[6] Van Dorsser, C. (2016) *Existing waterway infrastructures and future needs*, in Wiegmans B., and R. Konings, *Inland Waterway Transport Challenges and Prospects*, Routledge, New York.
[7] Press article (2013, 8 January) *Heinz, Bavaria en Mars gaan samen meer goederen over water vervoeren*, republished on http://www.bureauvoorlichtingbinnenvaart.nl/actueel/duplicate-of-bvb-haalt-in-the-blue-roadshow-ruim-11.800-vrachtwagens-naar-het-water.
[8] Press article (2015, 2 September), *BCTN en Danser samen continental naar Bazel*, published in Schuttevaer.
[9] European Commission (2011) *White Paper on transport, roadmap to a single European transport area – towards a competitive and resource-efficient transport system*, Office for Official Publications of the European Communities, Luxembourg.
[10] European Commission (2011) *A Roadmap for moving to a competitive low carbon economy in 2050*, COM(2011) 112 final.
[11] Koedijk, O.C. (2013) *Supplement to the Waterway Guidelines 2011*, RWS Water, Traffic and Environment, the Netherlands.
[12] Drewry (2015) *Container Census 2015: Survey and Forecast of Global Container Units*.
[13] IVR database (2013) *database listing all commercial inland vessels in Western Europe*, http://www.ivr.nl, data as per 1/3/2013.
[14] European Commission (2006) *Directive 2006/87/EC* (note see article 11.04 for present guidelines).
[15] Hekkenberg (2013) *Inland ships for efficient transport chains*, Delft, The Netherlands.
[16] Müller, E. (2003) *Innovative Transport Vehicles – Rhine*, Working Paper for project: European Strategies to Promote Inland Navigation, WG3 Intermodality & Interoperability.

Appendix A: CEMT ’92 Classification

Type de voies navigables / Type of inland waterway	Classe de voies navigables / Class of navigable waterway	Automoteurs et chalands / Motor vessels and barges — Type de bateaux: caractéristiques générales / Type of vessel: générales characteristics					Convois poussés / Pushed convoys — Type de convoi- Caractéristiques générales / Type of convoy- Générales characteristics				Hauteur minimale sous les ponts / Minimum height under bridges
		Dénomination / Designation	Longueur / Length	Largeur / Beam	Tirant déau / Draught	Tonnage / Tonnage	Longueur / Length	Largeur / Beam	Tirant déau / Draught	Tonnage / Tonnage	
			m	m	m	t	m	m	m	t	m
OF REGIONAL IMPORTANCE / D’INTERET REGIONAL	I	Péniche / Barge	38.50	5.05	1.80-2.20	250-400					4.00
	II	Kast-Caminois / Campine-Barge	50-55	6.60	2.50	4.00-650					4.00-5.00
	III	Gustav Koenings	67-80	8.20	2.50	650-1000					4.00-5.00
OF INTERNATIONAL IMPORTANCE / D’INTERET INTERNATIONAL	IV	Johan Welker	80-85	9.50	2.50	1000-1500	85	9.50	2.50-2.80	1250-1450	5.25/or 7.00
	Va	Grand bateaux Rhenands/Large Rhine Vessels	95-110	11.40	2.50-2.80	1500-3000	95-110	11.40	2.50-4.50	1600-3000	5.25/or 7.00/or 9.10
	Vb						172-185	11.40	2.50-4.50	3200-6000	
	VIa						95-110	22.80	2.50-4.50	3200-6000	7.10/or 9.10
	VIb		140	15.00	3.90		185-195	22.80	2.50-4.50	6400-12000	7.10/or 9.10
	VIc						270-280 193-200	22.80 33.00-34.20	2.50-4.50 2.50-4.50	9600-18000	9.10
	VII						285 195	33.00 34.20	2.50-4.50	14500-27000	9.10

Source: Waterway Guidelines 2011, Rijkswaterstaat [3]

Appendix B: Length requirements

Though we have not been requested to advice on the length of the vessels, we also consider the length very important. This appendix therefore defines the required length of the vessels for the efficient loading of continental containers in the ship's hold.

Table 2 already showed that the length of the hold is not optimal for CEMT II vessels and for vessels that are restricted by the maximum allowable length of 135 m on the Rhine.

Class II vessels could benefit substantially from an increase in length. Given the fact that Class II vessels are able to load 2.81 continental container lengths a slight 3 m increase in length should already be sufficient to increase the loading capacity by 50%. A slightly further increase of the length with another 2 m enables the use of better shaped and more fuel efficient vessels, that are more competitive and have a lower carbon footprint. From this point of view it is desirable to increase the allowable length on Class II waterways by 5 m from 55 m to 60 m.

Vessels of 135 m long (i.e. the longest indivisible vessels allowed on the Rhine) are able to load 17 TEU in front of each other, which corresponds to 7.56 continental container lengths. The optimal configuration is 18 TEU lengths. This configurations provides space for 8 continental containers lengths (i.e. a 5.9% higher capacity). For loading 18 TEU lengths a 140 m[1] barge is required, which is in fact similar to the length set for CEMT VIb motor vessels. The present guidelines for CEMT VIb motor vessels are therefore already optimal. The fact that vessels are built at the suboptimal length of 135 m is a result of the maximum length regulations that are in place on the Rhine.

The findings with respect to the required length of the vessels are summarized in Table B1.

Table B1: Required length for efficient transport of continental containers

Containers long	Class	Suggested Length	Note
3	CEMT II+	58 m – 60 m (60 m for lower fuel consumption and carbon footprint)	If the allowed length on the Class II waterways is increased by at least 3 m this increases the loading capacity for continental containers by 50%.
4	CEMT III	80 m	No changes required compared to present CEMT'92 system.
6	CEMT V	110 m	No changes required compared to present CEMT'92 system.
8	CEMT VIb	140 m	No changes required compared to present CEMT'92 system. Capacity is 5.9% higher than for vessels of 135 m as presently used on the Rhine.

With respect to the length we therefore conclude that, in particular, CEMT II waterways would benefit from an increase in length to at least 58 m and preferably 60 m. In addition the largest container vessels would benefit from an increase of the allowable length on the Rhine from 135 m to 140 m. The length of 140 m is similar to the length already set for CEMT VI motor vessels in the CEMT '92 classification. Increasing the length from 135 m to 140 m would increases the loading capacity for 20, 30, 40, and 45 foot containers with one additional container length.

[1] The Jowi is 134.16 m long and able to load 17 TEU lengths (this implies that a 135 m large barge would have at least 80 cm spare space in the hold). Assuming that it is possible to reduce the length of the accommodation by 30 cm, an increase in length from 135 m to 140 m should be sufficient to enable the loading of one extra TEU length (6.1 m).