

Bridge Construction Project Over The Loughor River

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Introduction

The site for the new bridge will be located across the River Loughor. It will have an Abutment either side of the river, with four Piers between the Abutments. These Piers will support the deck. Two Piers will be permanently sited in the water (Piers 2 and 3), and two Piers (Piers 1 and 4) will be sited on the inter-tidal zone between the river banks and the central Piers.

The river is tidal, so the foundations have to withstand the scour effect from the general river flow (especially when the river is in flood), and the scour effect from the ebb and flow of the tide, which can be very strong on 'spring' tides. With this in mind the foundations have to be particularly robust and substantial.

There will be five deck sections, each section will be twenty metres long (total length 100m). The deck will be eight metres above the water surface, eleven metres above the river bed (therefore the river depth will be three metres at the two central pier locations) and fifteen metres above the bearing layer.

All prices have been approximated from the SPON's Civil Engineering and Highway Work Price book 2018 (AECOM Ltd, 2017) and from the Crane Hire Rates PDF 2017 (Mattera, 2018).

Labour distribution

This project will run for twenty four hours a day, seven days a week.

The workforce will consist of four teams. Three of these teams will essentially be working on the whole project (team 1, 2 and 3), whilst the fourth team (team 4) will be brought in at the end of the project to lift and position the bridge deck spans.

The three teams will be allocated to three specific activities of the project.

Team 1 – Abutment 1 and Pier 1 (land based from one side of the river)

Team 2 – Abutment 2 and Pier 4 (land based from the other side of the river)

Team 3 – Piers 2 and 3 (river based from a jack-up barge)

Teams 1, 2 and 3 will be further split into two squads. One squad will be working for two weeks whilst the other squad will be on holiday for two weeks.

Each squad will be split into a 12 hour day shift and a 12 hour night shift.

Team 1 (Employed for $\frac{9}{10}$ of project)				Team 2 (Employed for $\frac{9}{10}$ of project)				Team 3 (Employed for $\frac{9}{10}$ of project)			
Squad 1		Squad 2		Squad 1		Squad 2		Squad 1		Squad 2	
Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night
Work	Work	Hol	Hol	Work	Work	Hol	Hol	Work	Work	Hol	Hol
Work	Work	Hol	Hol	Work	Work	Hol	Hol	Work	Work	Hol	Hol
Hol	Hol	Work	Work	Hol	Hol	Work	Work	Hol	Hol	Work	Work
Hol	Hol	Work	Work	Hol	Hol	Work	Work	Hol	Hol	Work	Work
Work	Work	Hol	Hol	Work	Work	Hol	Hol	Work	Work	Hol	Hol
Work	Work	Hol	Hol	Work	Work	Hol	Hol	Work	Work	Hol	Hol
Hol	Hol	Work	Work	Hol	Hol	Work	Work	Hol	Hol	Work	Work
Hol	Hol	Work	Work	Hol	Hol	Work	Work	Hol	Hol	Work	Work
Day = Day Shift. Night = Night Shift. Hol = Holidays This pattern continues until the project tasks / activities are completed											

Team 4 (Employed for the last 3 weeks)	
Day Shift	Night Shift
Work	Work
Work	Work
Work	Work
This team works the full three weeks until the bridge deck spans are installed	

Justification for a 24/7 work pattern

The work schedule will consist of 24 hours a day, 7 days a week. This will not disrupt local residence as there is constant busy traffic passing this location of which generate noise levels above what noise will be created by the construction process, with exception to the piling operations. These piling operations will therefore be undertaken during the day shift.

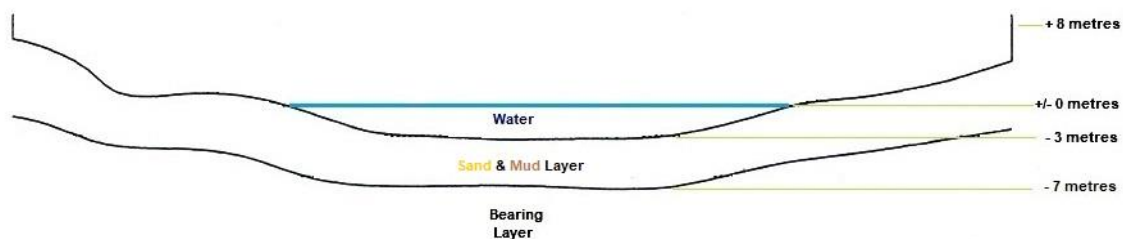
Another very important reason for working 24 / 7 is to make use of the best times in utilising the tides, which vary during any 24 hour period. For example – getting the excavators / suction pumps onto the sandy shoreline to excavate the foundations for Piers 1 and 4 will only be possible at certain stated of the tide, which might be during the night.

General Activity

There are five general activities undertaken by the four teams.

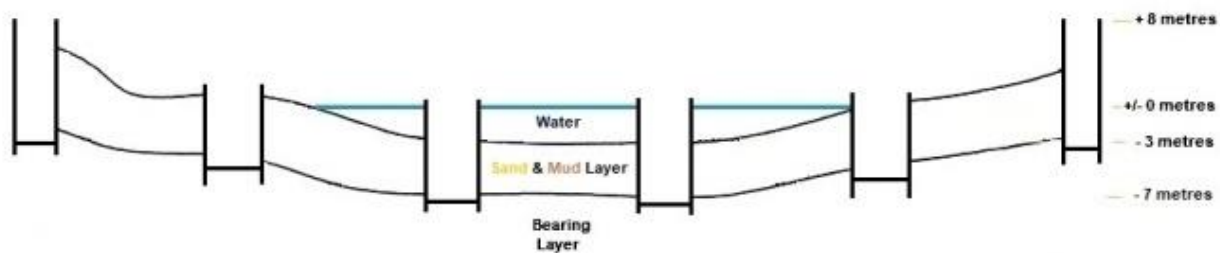
- Installation of the pre-fabricated reinforced concrete caissons for abutment and pier foundations, followed by excavation down to bearing layer.
- Installation of the foundation piles within the caissons.
- Installation of steel reinforcement bar and pouring of concrete for pile caps and filling of caissons.
- Construction of reinforced concrete piers
- Installation of pre-fabricated steel bridge deck spans.

Site - Before Bridge Construction



General Activity 1

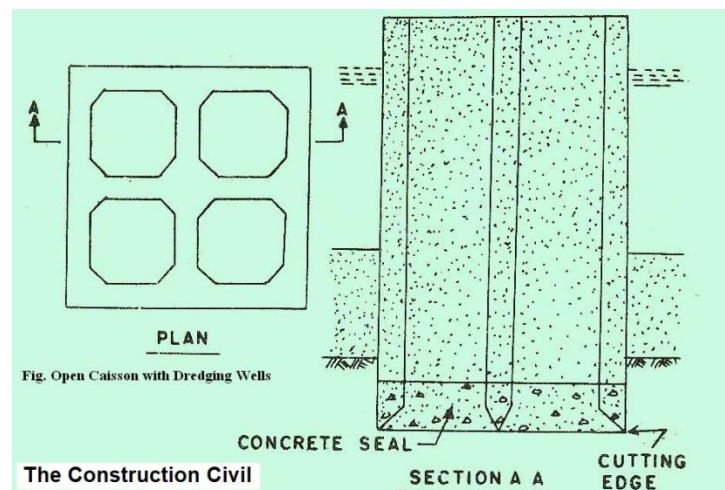
Pre-fabricated Reinforced Concrete Caissons for Abutment and Pier Foundations, Followed by Excavation Down to Bearing Layer



Caisson foundations will be used for all the four piers and the two abutments. They will be the open caisson type with dredging wells. The Caissons will be pre-cast and made of reinforced concrete.



(ZWEIG GROUP, 2014)



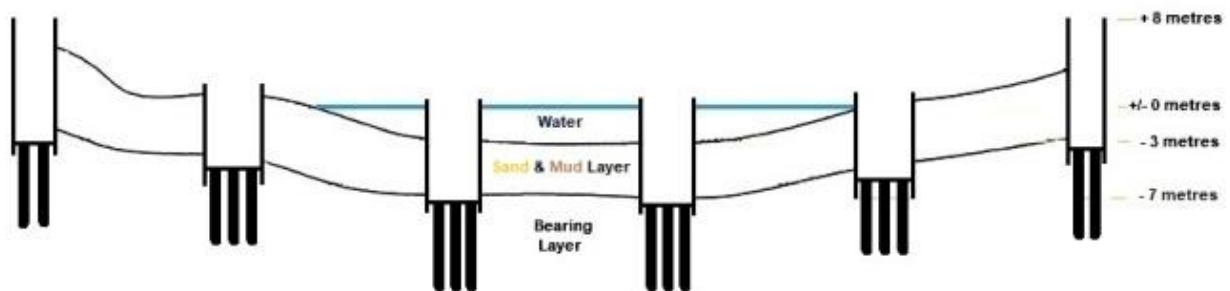
(The Construction Civil - Caissons, 2018)

This type of caisson is ideal for bridge pier foundations and abutments (The Construction Civil - Caissons, 2018).

Once they have been sunk into position the internal sand / mud will be removed until the caissons are sitting on the bearing layer. They will be further stabilised by hammering piles into the bearing layer for added stability against the dual forces created by river and strong 'spring' tides. The caisson voids will then be filled with reinforced concrete.

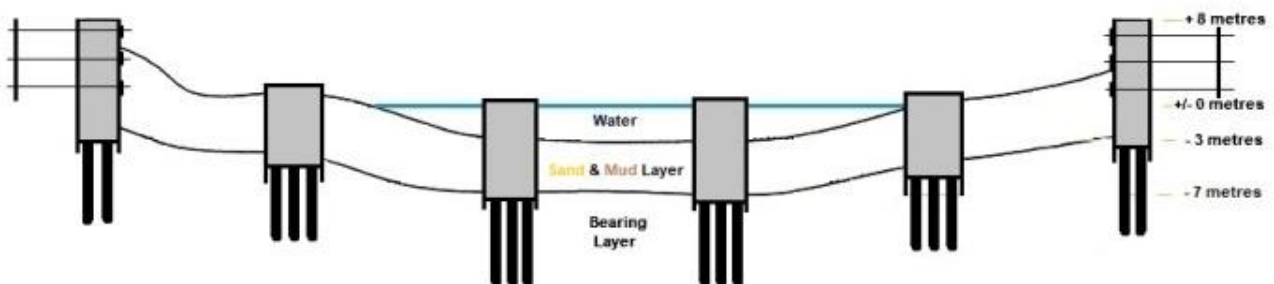
General Activity 2

Foundation Piling



General Activity 3

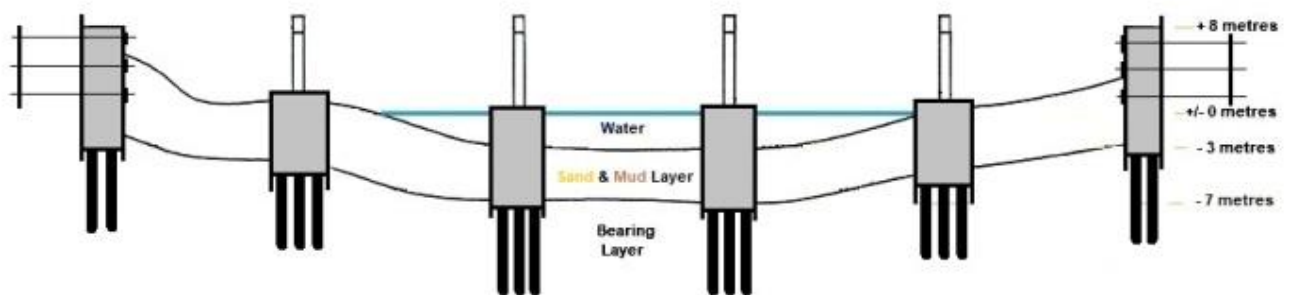
Concrete Pile Caps And Concrete Foundation Construction



When sourcing a supplier of concrete for the bridge foundations there is a 'ready mix' supplier in Llanelli (Breedon) who is less than five miles away from the construction site, so according to the Spon's Work Price Book 2018 for Civil Engineering and Highways (AECOM Ltd, 2017. p199), there will be no need to pay for additional mileage costs. The type of concrete that will be needed will be a sulphate resistant mix due to the fact it is to be used in the construction of a 'Marine Structure' (The Construction Civil - Sulphate Resistant Cement, 2018).

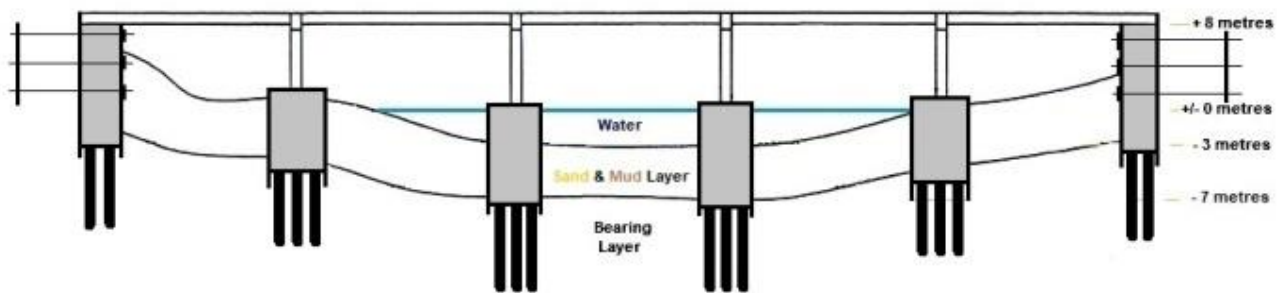
General Activity 4

Pier Construction



General Activity 5

Pre-fabricated Steel Deck Installation



Calculated results discussion

Following the first estimation for the calculation costs of every individual major task, the total figure arrived at could be classed as rather high for this type of project (£7,266,818). The SPON's price book 2018 (page 107) indicates that a whole bridge, with 5 spans of 20m long (10m wide) should cost no more than 5.5 million pounds. However, with further 'activity cost analysis' the project cost could be reduced. This also applies to the labour, which could also be reduced if closely scrutinised, which in turn could produce another cost saving.

Conclusion

This bridge project has been planned as a 'fast track' venture to cause as little disruption to commuters and local residents. Many of the main components have been constructed offsite prior to the main onsite project commencement. This will drastically reduce onsite construction time.

References

AECOM Ltd (2017) *Spon's civil engineering and highway works price book 2018 Thirty-second edition*.

Mattera, M. D. (2018) 'Crane hire rates 2017/18. A pretty good year.', *Rn*, 57, p. 7.

The Construction Civil - Caissons (2018) *Caissons-Types of caissons*. Available at: <https://www.theconstructioncivil.org/caissons-types-of-caissons/> (Accessed: 10 January 2018).

The Construction Civil - Sulphate Resistant Cement (2018) *Sulphate Resisting Cement*. Available at: <https://www.theconstructioncivil.org/sulphate-resisting-cement/> (Accessed: 10 January 2018).

ZWEIG GROUP (2014) *Civil + Structural Engineer*. Available at: <https://csengineermag.com/article/history-in-the-making-again/> (Accessed: 10 January 2018).

Appendix

Gantt chart – general bridge construction activities



Spreadsheet - labour distribution throughout bridge construction activities

Loughor Bridge Labour (Distributed throughout different project activities)																						
			'Off site' manufacture	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14	Week 15	Week 16	Week 17	Week 18	Week 19
Team 1	Abutment 1	Caisson manufacture	38																			
	Abutment 1	Caisson positioning		14																		
	Abutment 1	Caisson excavation			10	10																
	Abutment 1	Caisson foundation piling					4															
	Abutment 1	Anchor ties						8														
	Abutment 1	Caisson concrete pour							14													
	Pier 1	Caisson manufacture	38																			
	Pier 1	Caisson positioning								14	14											
	Pier 1	Caisson excavation										10	10									
	Pier 1	Caisson foundation piling												4								
	Pier 1	Caisson concrete pour													14							
	Pier 1	Masonry work														38	38	38	38			
Team 2	Abutment 2	Caisson manufacture	38																			
	Abutment 2	Caisson positioning		14																		
	Abutment 2	Caisson excavation			10	10																
	Abutment 2	Caisson foundation piling					4															
	Abutment 2	Anchor ties						8														
	Abutment 2	Caisson concrete pour							14													
	Pier 4	Caisson manufacture	38																			
	Pier 4	Caisson positioning								14	14											
	Pier 4	Caisson excavation										10	10									
	Pier 4	Caisson foundation piling												4								
	Pier 4	Caisson concrete pour													14							
	Pier 4	Masonry work														38	38	38	38			
Team 3	Pier 2 & 3	2 x caisson manufacture	38																			
	Pier 2 & 3	Barge mobilization + 2 x caisson positioning		20	20																	
	Pier 2 & 3	2 x caisson excavation				16	16	16	16													
	Pier 2 & 3	2 x caisson foundation piling								4	4											
	Pier 2 & 3	2 x caisson concrete pour										14	14									
	Pier 2 & 3	Masonry work												38	38	38	38	38	38			
Team 4	Bridge deck spans	5 x bridge deck span manufacture	42																			
	Bridge span 1	Crane lift and position																		18		
	Bridge span 5	Crane lift and position																		18		
	Bridge span 2	Crane lift and position																			18	
	Bridge span 4	Crane lift and position																			18	
	Bridge span 3	Crane lift and position																				16
	Total Labour offsite & per Week		232	48	40	36	24	32	44	32	32	34	34	46	66	114	114	114	114	36	36	16
	Total Labour for the whole project		1244																			

Spreadsheet – cost distribution throughout bridge construction activities

Loughor Bridge Costs [£] (Distributed throughout different project activities)																						
			'Off site' manufacture	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14	Week 15	Week 16	Week 17	Week 18	Week 19
Team 1	Abutment 1	Caisson manufacture	781000																			
	Abutment 1	Caisson positioning		30000																		
	Abutment 1	Caisson excavation			4250	4250																
	Abutment 1	Caisson foundation piling					26150															
	Abutment 1	Anchor ties						47000														
	Abutment 1	Caisson concrete pour							60805													
	Pier 1	Caisson manufacture	781000																			
	Pier 1	Caisson positioning								20000	20000											
	Pier 1	Caisson excavation										4250	4250									
	Pier 1	Caisson foundation piling												26150								
	Pier 1	Caisson concrete pour													60805							
	Pier 1	Masonry work														60250	60250	60250	60250			
Team 2	Abutment 2	Caisson manufacture	781000																			
	Abutment 2	Caisson positioning		30000																		
	Abutment 2	Caisson excavation			4250	4250																
	Abutment 2	Caisson foundation piling					26150															
	Abutment 2	Anchor ties						47000														
	Abutment 2	Caisson concrete pour							60805													
	Pier 4	Caisson manufacture	781000																			
	Pier 4	Caisson positioning								20000	20000											
	Pier 4	Caisson excavation										4250	4250									
	Pier 4	Caisson foundation piling												26150								
	Pier 4	Caisson concrete pour													60805							
	Pier 4	Masonry work														60250	60250	60250	60250			
Team 3	Pier 2 & 3	2 x caisson manufacture	1562000																			
	Pier 2 & 3	Barge mobilization + 2 x caisson positioning		185000	185000																	
	Pier 2 & 3	2 x caisson excavation				4250	4250	4250	4250													
	Pier 2 & 3	2 x caisson foundation piling								26500	26500											
	Pier 2 & 3	2 x caisson concrete pour										61000	61000									
	Pier 2 & 3	Masonry work												94333	94333	94333	94333	94333	94333			
Team 4	Bridge deck spans	5 x bridge deck span manufacture	165000																			
	Bridge span 1	Crane lift and position																		40000		
	Bridge span 5	Crane lift and position																		40000		
	Bridge span 2	Crane lift and position																			40000	
	Bridge span 4	Crane lift and position																			40000	
	Bridge span 3	Crane lift and position																				30000
	Total Costs (£) offsite & per Week		4851000	245000	193500	12750	56550	98250	125860	66500	66500	69500	69500	146633	215943	214833	214833	214833	214833	80000	80000	30000
	Total Cost (£) for the whole project		7266818																			

Tables - resources and costs

Loughor Bridge Construction Resources and Cost				
Team 1				
General Activity		Resources - Labour	Resources - Plant	Activity Cost
Abutment 1	Caisson manufacture (Pre-cast, off site)	2 x formwork supervisors (split day and night) 4 x formwork joiners (split day and night) 2 x formwork labourers (split day and night) 2 x reinforcement steel fixers (split day and night) 2 x reinforcement steel labourers (split day and night) 2 x crane operators (split day and night) 2 x crane supervisors (split day and night) 4 x slingers (split day and night) 4 x banksmen (split day and night) 2 x concrete pour supervisor (split day and night) 4 x concrete pour labourers (split day and night) 6 x concrete lorry drivers (split day and night) 2 x pump/equipment mechanics (split day and night)	Carpenters tools 1 x reinforcement bending equipment 1 x crane 3 x concrete lorry's 1 x concrete pump and chute	£781000
Abutment 1	Caisson positioning	2 x lorry drive (delivery during the day) 2 x crane operators (split day and night) 2 x crane supervisors (split day and night) 4 x slingers (split day and night) 4 x banksmen (split day and night)	1 x articulated delivery lorry 1 x crane	£30000
Abutment 1	Caisson excavation	2 x excavator operator (split day and night) 4 x lorry drivers (split day and night) 4 x banksmen (split day and night)	1 x excavator 2 x lorry's	£8500
Abutment 1	Caisson foundation piling ('Down Time' 8pm-8am quiet period)	1 x supervisor (days only due to noise) 1 x equipment operator (days only due to noise) 2 x labourer (days only due to noise)	1 x Pile Driving Equipment	£26150
Abutment 1	Anchor ties	2 x equipment operators (split day and night) 2 x supervisor (split day and night) 4 x labourers (split day and night)	1 x angled drilling equipment 1 x grouting equipment 1 x tensioning equipment	£47000
Abutment 1	Caisson concrete pour	6 x concrete lorry drivers (split day and night) 2 x supervisor (split day and night) 2 x pump/equipment mechanics (split day and night) 4 x labourers (split day and night)	3 x concrete lorry's 1 x concrete pump and chute	£60805
Pier 1	Caisson manufacture (Pre-cast, off site)	2 x formwork supervisors (split day and night) 4 x formwork joiners (split day and night) 2 x formwork labourers (split day and night)	Carpenters tools 1 x reinforcement bending equipment 1 x crane	£781000

		2 x reinforcement steel fixers (split day and night) 2 x reinforcement steel labourers (split day and night) 2 x crane operators (split day and night) 2 x crane supervisors (split day and night) 4 x slingers (split day and night) 4 x banksmen (split day and night) 2 x concrete pour supervisor (split day and night) 4 x concrete pour labourers (split day and night) 6 x concrete lorry drivers (split day and night) 2 x pump/equipment mechanics (split day and night)	3 x concrete lorry's 1 x concrete pump and chute	
Pier 1	Caisson positioning	2 x lorry drive (delivery during the day) 2 x crane operators (split day and night) 2 x crane supervisors (split day and night) 4 x slingers (split day and night) 4 x banksmen (split day and night)	1 x articulated delivery lorry 1 x crane	£40000
Pier 1	Caisson excavation	2 x excavator operator (split day and night) 4 x lorry drivers (split day and night) 4 x banksmen (split day and night)	1 x excavator 2 x lorry's	£8500
Pier 1	Caisson foundation piling ('Down Time' 8pm-8am quiet period)	1 x supervisor (days only due to noise) 1 x equipment operator (days only due to noise) 2 x labourer (days only due to noise)	1 x Pile Driving Equipment	£26150
Pier 1	Caisson concrete pour	6 x concrete lorry drivers (split day and night) 2 x supervisor (split day and night) 2 x pump/equipment mechanics (split day and night) 4 x labourers (split day and night)	3 x concrete lorry's 1 x concrete pump and chute	£60805
Pier 1	Masonry work	2 x formwork supervisors (split day and night) 4 x formwork joiners (split day and night) 2 x formwork labourers (split day and night) 2 x reinforcement steel fixers (split day and night) 2 x reinforcement steel labourers (split day and night) 2 x crane operators (split day and night) 2 x crane supervisors (split day and night) 4 x slingers (split day and night) 4 x banksmen (split day and night) 2 x concrete pour supervisor (split day and night) 4 x concrete pour labourers (split day and night) 6 x concrete lorry drivers (split day and night) 2 x pump/equipment mechanics (split day and night)	Carpenters tools 1 x reinforcement bending equipment 1 x crane 3 x concrete lorry's 1 x concrete pump and chute	£241000

Loughor Bridge Construction Resources and Cost

Team 2

General Activity		Resources - Labour	Resources - Plant	Activity Cost
Abutment 2	Caisson manufacture (Pre-cast, off site)	2 x formwork supervisors (split day and night) 4 x formwork joiners (split day and night) 2 x formwork labourers (split day and night) 2 x reinforcement steel fixers (split day and night) 2 x reinforcement steel labourers (split day and night) 2 x crane operators (split day and night) 2 x crane supervisors (split day and night) 4 x slingers (split day and night) 4 x banksmen (split day and night) 2 x concrete pour supervisor (split day and night) 4 x concrete pour labourers (split day and night) 6 x concrete lorry drivers (split day and night) 2 x pump/equipment mechanics (split day and night)	Carpenters tools 1 x reinforcement bending equipment 1 x crane 3 x concrete lorry's 1 x concrete pump and chute	£781000
Abutment 2	Caisson positioning	2 x lorry drive (delivery during the day) 2 x crane operators (split day and night) 2 x crane supervisors (split day and night) 4 x slingers (split day and night) 4 x banksmen (split day and night)	1 x articulated delivery lorry 1 x crane	£30000
Abutment 2	Caisson excavation	2 x excavator operator (split day and night) 4 x lorry drivers (split day and night) 4 x banksmen (split day and night)	1 x excavator 2 x lorry's	£8500
Abutment 2	Caisson foundation piling ('Down Time' 8pm-8am quiet period)	1 x supervisor (days only due to noise) 1 x equipment operator (days only due to noise) 2 x labourer (days only due to noise)	1 x Pile Driving Equipment	£26150
Abutment 2	Anchor ties	2 x equipment operators (split day and night) 2 x supervisor (split day and night) 4 x labourers (split day and night)	1 x angled drilling equipment 1 x grouting equipment 1 x tensioning equipment	£47000
Abutment 2	Caisson concrete pour	6 x concrete lorry drivers (split day and night) 2 x supervisor (split day and night) 2 x pump/equipment mechanics (split day and night) 4 x labourers (split day and night)	3 x concrete lorry's 1 x concrete pump and chute	£60805
Pier 4	Caisson manufacture (Pre-cast, off site)	2 x formwork supervisors (split day and night) 4 x formwork joiners (split day and night) 2 x formwork labourers (split day and night) 2 x reinforcement steel fixers (split day and night)	Carpenters tools 1 x reinforcement bending equipment 1 x crane 3 x concrete lorry's	£781000

		2 x reinforcement steel labourers (split day and night) 2 x crane operators (split day and night) 2 x crane supervisors (split day and night) 4 x slingers (split day and night) 4 x banksmen (split day and night) 2 x concrete pour supervisor (split day and night) 4 x concrete pour labourers (split day and night) 6 x concrete lorry drivers (split day and night) 2 x pump/equipment mechanics (split day and night)	1 x concrete pump and chute	
Pier 4	Caisson positioning	2 x lorry drive (delivery during the day) 2 x crane operators (split day and night) 2 x crane supervisors (split day and night) 4 x slingers (split day and night) 4 x banksmen (split day and night)	1 x articulated delivery lorry 1 x crane	£40000
Pier 4	Caisson excavation	2 x excavator operator (split day and night) 4 x lorry drivers (split day and night) 4 x banksmen (split day and night)	1 x excavator 2 x lorry's	£8500
Pier 4	Caisson foundation piling ('Down Time' 8pm-8am quiet period)	1 x supervisor (days only due to noise) 1 x equipment operator (days only due to noise) 2 x labourer (days only due to noise)	1 x Pile Driving Equipment	£26150
Pier 4	Caisson concrete pour	6 x concrete lorry drivers (split day and night) 2 x supervisor (split day and night) 2 x pump/equipment mechanics (split day and night) 4 x labourers (split day and night)	3 x concrete lorry's 1 x concrete pump and chute	£60805
Pier 4	Masonry work	2 x formwork supervisors (split day and night) 4 x formwork joiners (split day and night) 2 x formwork labourers (split day and night) 2 x reinforcement steel fixers (split day and night) 2 x reinforcement steel labourers (split day and night) 2 x crane operators (split day and night) 2 x crane supervisors (split day and night) 4 x slingers (split day and night) 4 x banksmen (split day and night) 2 x concrete pour supervisor (split day and night) 4 x concrete pour labourers (split day and night) 6 x concrete lorry drivers (split day and night) 2 x pump/equipment mechanics (split day and night)	Carpenters tools 1 x reinforcement bending equipment 1 x crane 3 x concrete lorry's 1 x concrete pump and chute	£241000

Loughor Bridge Construction Resources and Cost

Team 3

General Activity		Resources - Labour	Resources - Plant	Activity Cost
Pier 2 & 3	2 x Caisson manufacture (Pre-cast, off site)	2 x formwork supervisors (split day and night) 4 x formwork joiners (split day and night) 2 x formwork labourers (split day and night) 2 x reinforcement steel fixers (split day and night) 2 x reinforcement steel labourers (split day and night) 2 x crane operators (split day and night) 2 x crane supervisors (split day and night) 4 x slingers (split day and night) 4 x banksmen (split day and night) 2 x concrete pour supervisor (split day and night) 4 x concrete pour labourers (split day and night) 6 x concrete lorry drivers (split day and night) 2 x pump/equipment mechanics (split day and night)	Carpenters tools 1 x reinforcement bending equipment 1 x crane 3 x concrete lorry's 1 x concrete pump and chute	£1562000
Pier 2 & 3	Jack-up barge mobilization and 2 x caisson positioning	2 x lorry drive (delivering caissons during the day) 2 x barge crane operators (split day and night) 2 x barge crane supervisors (split day and night) 4 x barge slingers (split day and night) 4 x barge banksmen (split day and night) 4 x barge labourers (split day and night)	1 x articulated delivery lorry 1 x jack-up barge 1 x crane	£310000 (mob) £60000 (lifts)
Pier 2 & 3	2 x Caisson excavation	2 x barge crane operators (split day and night) 2 x barge crane supervisors (split day and night) 4 x barge slingers (split day and night) 4 x barge banksmen (split day and night) 4 x barge labourers (split day and night)	1 x crane (operating grab)	£17000
Pier 2 & 3	Caisson foundation piling (x2) ('Down Time' 8pm-8am quiet period)	1 x supervisor (days only due to noise) 1 x equipment operator (days only due to noise) 2 x labourer (days only due to noise)	1 x Pile Driving Equipment	£53000
Pier 2 & 3	Caisson concrete pour (x2)	6 x concrete lorry drivers (split day and night) 2 x supervisor (split day and night) 2 x pump/equipment mechanics (split day and night) 4 x labourers (split day and night)	3 x concrete lorry's 1 x concrete pump and chute	£122000
Pier 2 & 3	Masonry work	2 x formwork supervisors (split day and night) 4 x formwork joiners (split day and night) 2 x formwork labourers (split day and night) 2 x reinforcement steel fixers (split day and night)	Carpenters tools 1 x reinforcement bending equipment 1 x crane 3 x concrete lorry's	£566000

		2 x reinforcement steel labourers (split day and night) 2 x crane operators (split day and night) 2 x crane supervisors (split day and night) 4 x slingers (split day and night) 4 x banksmen (split day and night) 2 x concrete pour supervisor (split day and night) 4 x concrete pour labourers (split day and night) 6 x concrete lorry drivers (split day and night) 2 x pump/equipment mechanics (split day and night)	1 x concrete pump and chute	
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Loughor Bridge Construction Resources and Cost

Team 4

General Activity		Resources - Labour	Resources - Plant	Activity Cost
Bridge deck 1, 2,3,4,5.	5 x bridge deck manufacture (off site)	2 x steel erector supervisors (split day and night) 6 x steel erectors (split day and night) 4 x welders / burners (split day and night) 2 x reinforcement steel fixers (split day and night) 2 x reinforcement steel labourers (split day and night) 2 x crane operators (split day and night) 2 x crane supervisors (split day and night) 4 x slingers (split day and night) 4 x banksmen (split day and night) 2 x concrete pour supervisor (split day and night) 4 x concrete pour labourers (split day and night) 6 x concrete lorry drivers (split day and night) 2 x pump/equipment mechanics (split day and night)	Welding equipment Reinforcement bending equipment 1 x crane 3 x concrete lorry's 1 x concrete pump and chute	£165000
Bridge deck 1	Lift and place in position	2 x lorry drive (delivering bridge span during the day) 2 x crane operators (split day and night) 2 x crane supervisors (split day and night) 4 x slingers (split day and night) 4 x banksmen (split day and night) 4 x labourers (split day and night)	1 x articulated delivery lorry 1 x shore side crane	£40000
Bridge deck 5	Lift and place in position	2 x lorry drive (delivering bridge span during the day) 2 x crane operators (split day and night) 2 x crane supervisors (split day and night) 4 x slingers (split day and night) 4 x banksmen (split day and night) 4 x labourers (split day and night)	1 x articulated delivery lorry 1 x shore side crane	£40000
Bridge deck 2	Lift and place in position	2 x lorry drive (delivering bridge span during the day) 2 x crane operators (split day and night) 2 x crane supervisors (split day and night) 4 x slingers (split day and night) 4 x banksmen (split day and night) 4 x labourers (split day and night)	1 x articulated delivery lorry 1 x shore side crane	£40000
Bridge deck 4	Lift and place in position	2 x lorry drive (delivering bridge span during the day) 2 x crane operators (split day and night)	1 x articulated delivery lorry 1 x shore side crane	£40000

		2 x crane supervisors (split day and night) 4 x slingers (split day and night) 4 x banksmen (split day and night) 4 x labourers (split day and night)		
Bridge deck 3	Lift and place in position	2 x barge crane operators (split day and night) 2 x barge crane supervisors (split day and night) 4 x barge slingers (split day and night) 4 x barge banksmen (split day and night) 4 x barge labourers (split day and night)	1 x jack-up barge 1 x jack-up barge crane	£30000

ACTIVITY COST CALCULATIONS

TEAM 1

Abutment 1

Caisson manufacture – pre cast, off site. (SPON's, 2018. p105)

Reinforced concrete river caisson area

Front area = Height 12m x width 12m = 144m²

Rear area = Height 12m x width 12m = 144m²

2 x side areas = Height 12m x depth 5m x 2 = 120m² = 240m²

Interior segment dividing walls = approximately 288m² + (4 x 60m²) = 240m²

Total reinforced concrete used = 144m²+144m²+240m²+240m²+288m²=1056m² So say 1100m²

@ £710 per m² - one abutment caisson will cost **£781000**

Caisson positioning (Mattera, 2018)

Weight of Caisson (if condensed into a solid cube of 12m x 3m x 2m = 72m³ of reinforce concrete)

Reinforced concrete weighs approx. 2.5 tonne per m³.

So 2.5 tonnes / m³ x 72m³ = 180 tonnes

So each caisson will weigh 180 tonnes

So for abutment caisson lift – hire a crane that can lift 180 Tonnes at a radius of **10m** and personnel = estimated **£30000**

Caisson excavation (SPON's 2018. p 184)

Approximately 7m deep to excavate x 10m wide x 5m = 350m³ to excavate

So for 5m to 10m depth it cost £24.01 to excavate m³ = 350 x 24.01 = £8403.50 Round up to **£8500**

Caisson foundation piling (SPON's 2018. p 285)

100 steel bearing piles (mass 175kg/m), 10m long = £7194.35. = £71.95 each. Say £72 each.

Abutment 1 will use 20 piles = £1440.

Piles will be driven to a depth of 8m into the bearing layer @ £5.21 per metre driven.

So $8 \times 20 \times £5.21 = £833.60$. Say £834

Total for steel bearing piles = £1440 + £834 = £2274. Round up to £2300

Equipment 'standing time' (down time) No piling during 8pm to 8am due to noise disturbing nearby residents.

12 hours equipment down time in every 24 hours @ £283.90 per hour.

Equipment on hire for 7 days = $12\text{hrs} \times 7\text{days} \times £283.90 = £23847.60$. Round up to £23850

Total cost for performing this task = £23850 + £2300 = **£26150**

Anchor ties - AKA ground anchors (SPON's 2018. p 170)

50 ground anchors

Cost to hire equipment = £13360.83 (No Standing Time – working the equipment 24/7). Round up to £13500.00

Maximum drilling depth - 15m into rock, alluvial (muddy, sandy sediment) or clay, with a holding load of up to 50 tonnes each anchor @£44.94 per metre.

So $15\text{m} \times 50 \text{ ground anchors} \times £44.94 = £33705.00$. Round down to £33500.00

Total cost for performing this task = £13500 + £33500 = **£47000**

Caisson concrete pours (SPON's 2018. p 200 & 203)

Approximate volume of caisson to fill with foundation reinforced concrete = 7m deep x 10m wide x 5m = 350m³.

Provision of concrete. Grade C30 sulphate resistant concrete (used for marine structures) costs £143 per m³. So $£143 \times 350\text{m}^3 = £50050$

Placing of reinforced concrete costs £30.73 per m³. So $£30.73 \times 350\text{m}^3 = £10755.50$

Total cost for performing this task = £50050 + £10755.50 = **£60805**

ACTIVITY COST CALCULATIONS

TEAM 1

Pier 1

Caisson manufacture – pre cast, off site. (Spon's 2018. p 105)

Reinforced concrete river caisson area

Front area = Height 12m x width 12m = 144m²

Rear area = Height 12m x width 12m = 144m²

2 x side areas = Height 12m x depth 5m x 2 = 120m² = 240m²

Interior segment dividing walls = approximately 288m² + (4 x 60m²) = 240m²

Total reinforced concrete used = 144m²+144m²+240m²+240m²+288m²=1056m² So say 1100m²

@ £710 per m² - one pier caisson will cost **£781000**

Caisson positioning (Mattera, 2018)

Weight of Caisson (if condensed into a solid cube of 12m x 3m x 2m = 72m³ of reinforce concrete)

Reinforced concrete weighs approx. 2.5 tonne per m³.

So 2.5 tonnes / m³ x 72m³ = 180 tonnes

So each caisson will weigh 180 tonnes

So for pier 1 caisson lift – hire a crane that can lift 180 Tonnes at a radius of **30m** and personnel = estimated **£40000**

Caisson excavation (SPON's 2018. p 184)

Approximately 7m deep to excavate x 10m wide x 5m = 350m³ to excavate

So for 5m to 10m depth it cost £24.01 to excavate m³ = 350 x 24.01 = £8403.50 Round up to **£8500**

Caisson foundation piling (SPON's 2018. p 285)

100 steel bearing piles (mass 175kg/m), 10m long = £7194.35. = £71.95 each. Say £72 each.

Pier 1 will use 20 piles = £1440.

Piles will be driven to a depth of 8m into the bearing layer @ £5.21 per metre driven.

So $8 \times 20 \times £5.21 = £833.60$. Say £834

Total for steel bearing piles = £1440 + £834 = £2274. Round up to £2300

Equipment 'standing time' (down time) No piling during 8pm to 8am due to noise disturbing nearby residents.

12 hours equipment down time in every 24 hours @ £283.90 per hour.

Equipment on hire for 7 days = 12hrs x 7days x £283.90 = £23847.60. Round up to £23850

Total cost for performing this task = £23850 + £2300 = **£26150**

Caisson concrete pours (SPON's 2018. p 200 & 203)

Approximate volume of caisson to fill with foundation reinforced concrete = 7m deep x 10m wide x 5m = 350m³.

Provision of concrete. Grade C30 sulphate resistant concrete (used for marine structures) costs £143 per m³. So $£143 \times 350\text{m}^3 = £50050$

Placing of reinforced concrete costs £30.73 per m³. So $£30.73 \times 350\text{m}^3 = £10755.50$

Total cost for performing this task = £50050 + £10755.50 = **£60805**

Masonry work (Spon's 2018. p 200 to 205)

Piers are 8m high x 10m long x 5m wide

Formwork m² = 8m x 10m x 2 = 160m² +

$$\underline{8\text{m} \times 5\text{m} \times 2 = 80\text{m}^2}$$

Total formwork required = 160m² + 80m² = 240m²

Formwork exceeding 1.22m high costs £62.24p per m²

So for formwork cost for one pier = £62.24p x 240m² = £14937.60 so round up to **£15000**

Reinforcement required to fill a pier volume approx. 400m³ (8m x 10m x 5m = 400m³)

Assuming 10cm gaps between mesh, therefore 98 rebar sheet x 8m = 784m² +

$$\underline{48 \text{ rebar sheet} \times 8\text{m} = 384\text{m}^2}$$

Total 1168m² of rebar required per pier

Reinforcement costs £8.19p per m² x 1168m² = £9565.92 so round up to **£10,000**

Reinforcement gang (onsite and offsite) = £180 per hour

Estimated 2 weeks work for handling and assembling reinforcement for pier 1 = 336 hours x £180 = £60480 so round up to **£61000**

Crane for lifting formwork, reinforcement and possible concrete hoppers (if concrete not pumped), required for the whole four week masonry period = £3000 per day x 28days = **£84000**

Concrete required to fill a pier with a volume of approx. 400m³

Provision of concrete. Grade C30 sulphate resistant concrete (used for marine structures) costs £143 per m³. So £143 x 400m³ = £57200 round up to **£58000**

Placing of reinforced concrete costs £30.73 per m³. So £30.73 x 400m³ = £12292 round up to **£13000**

Total cost for performing this task = £15000 + £10000 + £61000 + 84000 + £58000 + £13000 = **£241000**

ACTIVITY COST CALCULATIONS

TEAM 2

Abutment 2

Caisson manufacture – pre cast, off site. (SPON's, 2018. p105)

Reinforced concrete river caisson area

Front area = Height 12m x width 12m = 144m²

Rear area = Height 12m x width 12m = 144m²

2 x side areas = Height 12m x depth 5m x 2 = 120m² = 240m²

Interior segment dividing walls = approximately 288m² + (4 x 60m²) = 240m²

Total reinforced concrete used = 144m²+144m²+240m²+240m²+288m²=1056m² So say 1100m²

@ £710 per m² - one abutment caisson will cost **£781000**

Caisson positioning (Mattera, 2018)

Weight of Caisson (if condensed into a solid cube of 12m x 3m x 2m = 72m³ of reinforce concrete)

Reinforced concrete weighs approx. 2.5 tonne per m³.

So 2.5 tonnes / m³ x 72m³ = 180 tonnes

So each caisson will weigh 180 tonnes

So for abutment caisson lift – hire a crane that can lift 180 Tonnes at a radius of **10m** and personnel = estimated **£30000**

Caisson excavation (SPON's 2018. p 184)

Approximately 7m deep to excavate x 10m wide x 5m = 350m³ to excavate

So for 5m to 10m depth it cost £24.01 to excavate m³ = 350 x 24.01 = £8403.50 Round up to **£8500**

Caisson foundation piling (SPON's 2018. p 285)

100 steel bearing piles (mass 175kg/m), 10m long = £7194.35. = £71.95 each. Say £72 each.

Abutment 2 will use 20 piles = £1440.

Piles will be driven to a depth of 8m into the bearing layer @ £5.21 per metre driven.

So $8 \times 20 \times £5.21 = £833.60$. Say £834

Total for steel bearing piles = £1440 + £834 = £2274. Round up to £2300

Equipment 'standing time' (down time) No piling during 8pm to 8am due to noise disturbing nearby residents.

12 hours equipment down time in every 24 hours @ £283.90 per hour.

Equipment on hire for 7 days = $12\text{hrs} \times 7\text{days} \times £283.90 = £23847.60$. Round up to £23850

Total cost for performing this task = £23850 + £2300 = **£26150**

Anchor ties - AKA ground anchors (SPON's 2018. p 170)

50 ground anchors

Cost to hire equipment = £13360.83 (No Standing Time – working the equipment 24/7). Round up to £13500.00

Maximum drilling depth - 15m into rock, alluvial (muddy, sandy sediment) or clay, with a holding load of up to 50 tonnes each anchor @£44.94 per metre.

So $15\text{m} \times 50 \text{ ground anchors} \times £44.94 = £33705.00$. Round down to £33500.00

Total cost for performing this task = £13500 + £33500 = **£47000**

Caisson concrete pours (SPON's 2018. p 200 & 203)

Approximate volume of caisson to fill with foundation reinforced concrete = 7m deep x 10m wide x 5m = 350m³.

Provision of concrete. Grade C30 sulphate resistant concrete (used for marine structures) costs £143 per m³. So $£143 \times 350\text{m}^3 = £50050$

Placing of reinforced concrete costs £30.73 per m³. So $£30.73 \times 350\text{m}^3 = £10755.50$

Total cost for performing this task = £50050 + £10755.50 = **£60805**

ACTIVITY COST CALCULATIONS

TEAM 2

Pier 4

Caisson manufacture – pre cast, off site. (Spon's 2018. p 105)

Reinforced concrete river caisson area

Front area = Height 12m x width 12m = 144m²

Rear area = Height 12m x width 12m = 144m²

2 x side areas = Height 12m x depth 5m x 2 = 120m² = 240m²

Interior segment dividing walls = approximately 288m² + (4 x 60m²) = 240m²

Total reinforced concrete used = 144m²+144m²+240m²+240m²+288m²=1056m² So say 1100m²

@ £710 per m² - one pier caisson will cost **£781000**

Caisson positioning (Mattera, 2018)

Weight of Caisson (if condensed into a solid cube of 12m x 3m x 2m = 72m³ of reinforce concrete)

Reinforced concrete weighs approx. 2.5 tonne per m³.

So 2.5 tonnes / m³ x 72m³ = 180 tonnes

So each caisson will weigh 180 tonnes

So for pier 4 caisson lift – hire a crane that can lift 180 Tonnes at a radius of **30m** and personnel = estimated **£40000**

Caisson excavation (SPON's 2018. p 184)

Approximately 7m deep to excavate x 10m wide x 5m = 350m³ to excavate

So for 5m to 10m depth it cost £24.01 to excavate m³ = 350 x 24.01 = £8403.50 Round up to **£8500**

Caisson foundation piling (SPON's 2018. p 285)

100 steel bearing piles (mass 175kg/m), 10m long = £7194.35. = £71.95 each. Say £72 each.

Pier 4 will use 20 piles = £1440.

Piles will be driven to a depth of 8m into the bearing layer @ £5.21 per metre driven.

So $8 \times 20 \times £5.21 = £833.60$. Say £834

Total for steel bearing piles = £1440 + £834 = £2274. Round up to £2300

Equipment 'standing time' (down time) No piling during 8pm to 8am due to noise disturbing nearby residents.

12 hours equipment down time in every 24 hours @ £283.90 per hour.

Equipment on hire for 7 days = $12\text{hrs} \times 7\text{days} \times £283.90 = £23847.60$. Round up to £23850

Total cost for performing this task = £23850 + £2300 = **£26150**

Caisson concrete pours (SPON's 2018. p 200 & 203)

Approximate volume of caisson to fill with foundation reinforced concrete = 7m deep x 10m wide x 5m = 350m³.

Provision of concrete. Grade C30 sulphate resistant concrete (used for marine structures) costs £143 per m³. So $£143 \times 350\text{m}^3 = £50050$

Placing of reinforced concrete costs £30.73 per m³. So $£30.73 \times 350\text{m}^3 = £10755.50$

Total cost for performing this task = £50050 + £10755.50 = **£60805**

Masonry work (Spon's 2018. p 200 to 205)

Piers are 8m high x 10m long x 5m wide

Formwork m² = 8m x 10m x 2 = 160m² +

$$\underline{8\text{m} \times 5\text{m} \times 2 = 80\text{m}^2}$$

Total formwork required = 160m² + 80m² = 240m²

Formwork exceeding 1.22m high costs £62.24p per m²

So for formwork cost for one pier = £62.24p x 240m² = £14937.60 so round up to **£15000**

Reinforcement required to fill a pier volume approx. 400m³ (8m x 10m x 5m = 400m³)

Assuming 10cm gaps between mesh, therefore 98 rebar sheet x 8m = 784m² +

$$\underline{48 \text{ rebar sheet} \times 8\text{m} = 384\text{m}^2}$$

Total 1168m² of rebar required per pier

Reinforcement costs £8.19p per m² x 1168m² = £9565.92 so round up to **£10,000**

Reinforcement gang (onsite and offsite) = £180 per hour

Estimated 2 weeks work for handling and assembling reinforcement for pier 1 = 336 hours x £180 = £60480 so round up to **£61000**

Crane for lifting formwork, reinforcement and possible concrete hoppers (if concrete not pumped), required for the whole four week masonry period = £3000 per day x 28days = **£84000**

Concrete required to fill a pier with a volume of approx. 400m³

Provision of concrete. Grade C30 sulphate resistant concrete (used for marine structures) costs £143 per m³. So £143 x 400m³ = £57200 round up to **£58000**

Placing of reinforced concrete costs £30.73 per m³. So £30.73 x 400m³ = £12292 round up to **£13000**

Total cost for performing this task = £15000 + £10000 + £61000 + 84000 + £58000 + £13000 = **£241000**

ACTIVITY COST CALCULATIONS

TEAM 3

Pier 3 & 4

2 x caisson manufacture – pre cast, off site. (Spon's 2018. p 105)

Reinforced concrete river caisson area

Front area = Height 12m x width 12m = 144m²

Rear area = Height 12m x width 12m = 144m²

2 x side areas = Height 12m x depth 5m x 2 = 120m² = 240m²

Interior segment dividing walls = approximately 288m² + (4 x 60m²) = 240m²

Total reinforced concrete used = 144m²+144m²+240m²+240m²+288m²=1056m² So say 1100m²

@ £710 per m² - one pier caisson will cost £781000

2 x caissons = **£1,562,000**

Jack-up barge mobilization and utilization (Spon's 2018. p 181)

Barge / platform mobilization **£10000**

Barge / platform daily hire £5000 per week for 20 weeks = **£100000** (1 week contingency)

Large crane plus equipment on barge for 20 weeks @ £10000 week (1 week contingency and discounted for long hire period) = **£200000**

Total cost £10000 + £100000 + £200000 = **£310000**

2 x caisson positioning (Mattera, 2018)

Weight of Caisson (if condensed into a solid cube of 12m x 3m x 2m = 72m³ of reinforce concrete)

Reinforced concrete weighs approx. 2.5 tonne per m³.

So 2.5 tonnes / m³ x 72m³ = 180 tonnes

So each caisson will weigh 180 tonnes

So for pier 3 and 4 caisson lifts – each lift 180 Tonnes at a radius of **10m** and personnel = estimated £30000 x 2 = **£60000**

2 x caisson excavation (SPON's 2018. p 184)

Approximately 7m deep to excavate x 10m wide x 5m = 350m³ to excavate

So for 5m to 10m depth it cost £24.01 to excavate m³ = 350 x 24.01 = £8403.50 Round up to £8500 x 2 = **£17000**

2 x caisson foundation piling (SPON's 2018. p 285)

100 steel bearing piles (mass 175kg/m), 10m long = £7194.35. = £71.95 each. Say £72 each.

Pier 3 will use 20 piles = £1440. Pier 4 will be using 20 piles = £1440 each pier x 2. Total cost of piles = **£2880**

Piles will be driven to a depth of 8m into the bearing layer @ £5.21 per metre driven.

So 8 x 20 x £5.21 = £833.60. Say £834 x 2 = **£1668**

Equipment 'standing time' (down time) No piling during 8pm to 8am due to noise disturbing nearby residents.

12 hours equipment down time in every 24 hours @ £283.90 per hour.

Equipment on hire for 14 days = 12hrs x 14days x £283.90 = £47695. Round up to **£48000**

Total cost for performing this task = £52548 round up to **£53000**

2 x caisson concrete pours (SPON's 2018. p 200 & 203)

Approximate volume of caisson to fill with foundation reinforced concrete = 7m deep x 10m wide x 5m = 350m³.

Provision of concrete. Grade C30 sulphate resistant concrete (used for marine structures) costs £143 per m³. So £143 x 350m³ = £50050

Placing of reinforced concrete costs £30.73 per m³. So £30.73 x 350m³ = £10755.50

Total cost for performing this task = £50050 + £10755.50 = £60805 x 2 (2 caissons) = £121610 round up to **£122000**

2 x masonry work (Spon's 2018. p 200 to 205)

Piers are 8m high x 10m long x 5m wide

Formwork m² = 8m x 10m x 2 = 160m² +

$$\underline{8\text{m} \times 5\text{m} \times 2 = 80\text{m}^2}$$

Total formwork required = 160m² + 80m² = 240m²

Formwork exceeding 1.22m high costs £62.24p per m²

So for formwork cost for one pier = £62.24p x 240m² = £14937.60 so round up to **£15000**

Reinforcement required to fill a pier volume approx. 400m³ (8m x 10m x 5m = 400m³)

Assuming 10cm gaps between mesh, therefore 98 rebar sheet x 8m = 784m² +

$$\underline{48 \text{ rebar sheet} \times 8\text{m} = 384\text{m}^2}$$

Total 1168m² of rebar required per pier

Reinforcement costs £8.19p per m² x 1168m² = £9565.92 so round up to **£10,000**

Reinforcement gang (onsite and offsite) = £180 per hour

Estimated 2 weeks work for handling and assembling reinforcement for one pier = 336 hours
x £180 = £60480 so round up to **£61000**

Crane for lifting formwork, reinforcement and possible concrete hoppers (if concrete not pumped), required for the whole six week masonry period = £3000 per day x 42 days = **£126000**

Concrete required filling a pier with a volume of approx. 400m³

Provision of concrete. Grade C30 sulphate resistant concrete (used for marine structures) costs £143 per m³. So £143 x 400m³ = £57200 round up to **£58000**

Placing of reinforced concrete costs £30.73 per m³. So £30.73 x 400m³ = £12292 round up to **£13000**

Total cost for performing this task = £15000 + £10000 + £61000 + 126000 + £58000 + £13000 = £283000 x 2 (2 piers) = **£566000**

ACTIVITY COST CALCULATIONS

TEAM 4

Bridge deck spans

For the Loughor bridge the width of the bridge is 2 carriageways wide (single traffic each way), which will be approximately $1\text{m}+3\text{m}+2\text{m}+3\text{m}+1\text{m} = 10\text{m}$ wide.

So the squared meterage of one 20m long bridge deck span will be:-

$20\text{m long} \times 10\text{m wide} = 200\text{m}^2$

5 x bridge deck span offsite manufacture (Spon's 2018. p 117)

Steel frame, composite beam and concrete slab floor. £165 per m^2

So $165 \times 200 = £33000 \times 5 = \text{£165000}$

Bridge deck span crane lift into final position (Mattera, 2018)

Weight of bridge deck span approximately 180 tonnes

So for 2 lifts on one side of the river and 2 lifts on the other side of the river – hire a crane that can lift 180 Tonnes at a radius of **40m** from shore = estimated **£40000** per lift Total **£160000**

Note: Barge crane will lift the final middle section with the crane already sited on the barge.
Cost **£30000**