Comparison of bolted and welded splices

No. 1.09

Scope

For all except the shortest bridges (under 27 m overall length) site splices of the main girders are likely to be necessary, due to limitations of fabrication, transport or erection. Whether such splices should be welded or bolted is a frequent subject of discussion; each method of splicing has its advantages and disadvantages, not all of which are always recognised at the design stage. The purpose of this Note is to present a summary comparison of the two types, to aid the selection process. The comparison is made in tabular format, for ease of use.

BOLTED SPLICE	WELDED SPLICE
Appearance	
Bridge designers and clients can be oversensitive to the visual impact of bolted splices.	
Bolted splices are usually relatively small in outline (e.g. M24 bolts with a 15-20 mm thick bottom flange cover plates), will be painted the same colour as the remainder of the deck and are usually in the shadow of the cantilevers.	Cleaner line to steelwork. However, the welded beam will not be completely devoid of visible features; the position of the welded splices will still be observable, and deformation of thin stiffened webs (arising from weld distortion) may be visible in certain lighting conditions.
The use of bolted splices may be in keeping with the industrial nature of the area if there are, for example, riveted structures nearby.	
Bolted splices may occasionally be considered unacceptable in areas where pedestrians can observe the bridge at close quarters.	Welds may be ground flush for a landmark structure in a sensitive area (although care must then be used to avoid creating a visibly different surface texture).
The appearance is slightly better when the heads, rather than the nuts, are on the visible faces of the structure.	
Bolted splices are less noticeable when a dark shade of paint is used.	
For all columns in the central reserves of roads, beam splices equidistant on either side of each column look better than asymmetric positioning, although sometimes the solution is a single splice	
Structural performance	
A bolted joint may be designed for the loads at the splice position, not the full strength of the section.	A full strength joint is achieved with full penetration butt welds.
The splice detail generally does not govern fatigue life.	The splice detail may reduce fatigue life. - With plated and rolled sections, a class 112 detail can be achieved by using run-on and run-off plates, welding from both sides and grinding flush - see Table 8.3 of EN 1993-1-1. For plates thicker than 25 mm, a reduction applies. Without grinding flush, a class 90 detail is obtained. - When cope holes are provided (to allow access to make the flange butt welds) the opening creates a class 71 detail in the flange and in-

BOLTED SPLICE	WELDED SPLICE
	troduces a stress concentration factor of 2.4 in the web at the top of the hole (so it is best to avoid a butt weld in the web at the cope hole). It is best to butt weld an infill piece into the cope hole.
Practicality of Construction	
Cover plates and limited number of bolts can be used to support the girder during erection.	Temporary supports or landing beams required to support the girder until welding is complete. Temporary cleats also required to align joint (these have to be welded and removed later).
Easier control over finished shape of the girder can be exercised when templating techniques are used during fabrication and assembly to ensure accuracy in matching adjacent members. On the other hand, normal clearance bolt holes permit significant rotational adjustment and some longitudinal and vertical adjustment.	Less control over finished shape of the girder due to shrinkage and distortions caused by welding. On the other hand, longitudinal tolerances can be accommodated by varying weld gaps (but welding parameters may then need to be modified).
Splices can be completed by the erectors.	Qualified welders, working to approved procedures, are needed to complete splices, to ensure the required geometry.
Splice is not weather-dependent for bolting up. Tent around the splice not usually required. Joints will dry out naturally in warm weather, especially when protected by a deck.	Splice weather-dependent for welding (including pre-heat), metal spraying and completion of painting. A weatherproof tent around the splice is almost certainly required.
All welding, blast-cleaning, aluminium metal spraying and aluminium epoxy sealer application to the splice components is carried out in the shop, where application conditions are easier to control.	Site welding, cleaning, spraying and painting of spliced regions require greater attention and increased supervision, with application conditions being less easy to control (especially significant for blasting).
Economics	
The general rule is that bolted site splices are cheaper.	Welded site splices are generally more expensive because of costs of welding plant, procedure trials, protection of joints, NDT, electrode storage, addition/removal of fairing aids (to align parts to be welded) and additional restraints to beams.
Even for large jobs site bolting may still be more economic than welding because of the considerable reductions in time spent on site and, particularly, the duration of steel erection.	However, for large jobs (e.g. 500 connections, see Ref 1), welding may be more economical.
All blast cleaning carried out in the shop.	Blast cleaning around welds carried out on site. (The cost of this additional activity is probably accounted for in Ref 1)
All aluminium metal spray application carried out in the shop.	The extra expense of site metal spraying is not included in Ref 1, as metal spray is not always required.

BOLTED SPLICE	WELDED SPLICE
Lower supervisory costs.	Greater supervisory costs due to greater level of checking and requirement for specialist knowledge.
Less traffic disruption during erection of spans particularly over existing motorways.	Greater traffic disruption due to longer time required for diversion or protection while spans are erected and welded.
Less risk of delay to contract (see comments on programming).	Greater risk of delay to contract may be reflected in an increased contract sum.
Programming	
Bolting of splices takes less time than welding and can be programmed with greater certainty. Not all of the bolts need to be installed as a critical path activity.	Welding of splices will normally extend the time required for construction, particularly over existing roads. This is because it extends the critical path activities and because of: • need to erect tents around the splices to allow effective preheating and welding under all weather conditions • completion of welding; the multi-run welds required for a thick flange will take time • possible need for infilling of cope holes to achieve the required fatigue life • NDT of welds The minimum hold period before testing given in EN 1090-2 Table 23 (typically 40 hours for butt welds in S355 steel) is warranted, to safeguard against hydrogen cracking. This delay would then apply in addition to any repairs. • additional corrosion protection activities of blast cleaning, aluminium metal spraying and sealant coat application.
Little risk of remedial work, and probably only minor repainting, which could be done quickly or during closure for other work.	Greater risk of remedial work being required. Any welding remedial work could cause delay.
Negligible risk of delay to contract completion.	Risk of delay to contract completion if the construction of spans over a motorway (or, worse still, over a railway) is on the critical path.

General design comments

Whether bolting or welding a splice, it is good practice to place splices where forces are lowest (i.e. at points of contraflexure), and to enable connections to be completed with zero bending moment (this avoids extra jacking activity).

1. Hayward A and Weare F, Steel Detailer's Manual, Second Edition (revised by Oakhill), Blackwell Science, 2002

(See also references in GN 2.06).