*Proc. Instn Civ. Engrs*, Part 2, 1991, **91**, June, 373–375



# Steel–concrete composite girder with epoxy bonding

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In their Paper, Professor Prakash Rao and Dr Sharma draw the attention of the civil engineering profession to one possibility for using adhesives in a truly structural sense. The concept of forming structural adhesive shear connections between steel and hardened concrete was pioneered simultaneously in South Africa and France in the late 1960s.[5,6] The technique has been employed primarily for the flexural strengthening of concrete bridge decks, and there have been many publications on the subject in this and other journals.[7]

21. By 1975, well over 200 bridges in Japan had been strengthened by means of either steel plates or small I-sections bonded to the soffit of the concrete slabs, thus forming steel/concrete composite decks.[8] There are also reports on 'all-bonded' bridges which were constructed in East Germany after the early 1970s. One particular example[9] used epoxy resins in a variety of forms and locations on the superstructure. Of particular interest to this discussion is their successful use in forming the connection between the precast concrete deck slabs and the upper surface of the longitudinal steel girders.

22. Since the mid 1970s, the Wolfson Bridge Research Unit at the University of Dundee has been engaged in an extensive programme of adhesive research initiated by the concept of manufacturing a reinforced concrete slab in which the traditional bar reinforcement is replaced by a soffit steel plate. The novelty of the method lies in the use of epoxy based adhesives to form the necessary shear connection and the fact that the wet concrete is poured directly on to the freshly spread adhesive.[10]

23. It is with this background that we feel it appropriate to draw the reader's attention to some aspects of structural adhesive bonding which were not highlighted in the Paper. These are concerned in particular with the following: adhesive selection; surface preparation; stress distribution and anchorage; non-destructive testing; durability.

## Adhesive selection

24. The Authors will know that there are many types of epoxy adhesive, some curing at low temperatures and others at high temperatures. However, the reader could gain the impression that there is only one epoxy adhesive. Most epoxies that cure at normal ambient temperatures are of the two component type, comprising a resin and a hardener. There are many forms of epoxy resin and an even greater number of hardeners, the choice of which can affect significantly the mechanical and physical properties of the hardened system. Add to these a wide variety of additives in the form of fillers, diluents, plasticizers, toughening agents, etc., and it can readily be seen that material selection is not an easy task. Details on the engineering property requirements for structural adhesives and advice on adhesive

Paper published: *Proc. Instn Civ. Engrs*, Part 2, 1990, **89**, June, 251–260.

selection for steel/concrete bonding can be found in an earlier volume of the *Proceedings*.[11]

**Surface preparation**

25. The strength of bonded joints depends not only on the cohesive strength of the adhesive itself but also on the degree of adhesion to the bonding surface.[12] The most important factor in the durability of adhesive bonded joints is the environmental stability at the adhesive/substrate interface. Inadequate surface preparation is usually the main cause of durability problems and of joints failing in service. Concrete surfaces to be bonded need to be sound, uncontaminated and to have the surface laitance removed, preferably by grit blasting. For steel, all rust, millscale and dirt must first be removed by mechanical abrasion. The surfaces to be bonded then need to be degreased, using a suitable solvent. Finally, the surface should be grit blasted to grade ASa 2·5 of Swedish Standard SIS 055900,[13] using a clean, hard, angular metal grit, free of any contamination.

**Stress distribution and anchorage**

26. The Authors refer to the assumption of a uniform distribution of longitudinal shear stress over the shear span. This is reasonable provided that the structural cross-section is uniform throughout and there is an adequate length for anchorage of the steel/concrete bond beyond the point at which longitudinal transfer of stress is required. Changes in section can give rise to concentrated shear and peel stresses in the adhesive layer, which may call for special consideration of anchorage requirements. In applications involving steel plate bonding for the strengthening of concrete elements, supplementary bolting is often recommended at the plate ends in order to reduce any tendency towards peel failures.[7]

**Non-destructive testing**

27. The Paper discusses the use of ultrasonic pulse measurements to identify breakdown of the interfacial bond. It is our experience that devices such as the Pundit are capable of detecting gross delamination when there is an identifiable air gap at the interface. However, such techniques are not able to identify lack of bond in the absence of an air gap: for example, if there is grease or oil on the surface of the steel.

**Durability**

28. Bonded joint durability demands a twofold consideration of: the structural integrity of the cured adhesive; the stability of the adhesive/substrate interface.[11] Thus the correct choice of adhesive and an appreciation of the procedures necessary for the satisfactory fabrication of bonded assemblies are essential. Even with such care and attention there is still a lack of information on the long-term performance of resins. The Institutions of Civil and Structural Engineers' Standing Committee on Structural Safety has consistently highlighted this point and has warned against using resins in critical parts of a structure unless effective replacement can take place should structural deterioration occur.[14]

## Professor Prakash Rao and Dr Sharma

It is interesting to note the practical applications of epoxy bonding mentioned in Dr Mays and Professor Vardy's contribution, particularly in respect of bridge structure.

30. Quality and the type of epoxy adhesives do influence the performance of structures, as pointed out by the discussers. The epoxy used in the tests reported is

the two component type (resin and hardener), which cures at room temperature. The bond strength of epoxy depends on the nature of the surfaces as well. Extensive surface preparation described by the discussers (§ 25) was not carried out in the test program. However, it was ensured that the interface was free from any dirt or grease, and that the surfaces were cleaned thoroughly with coir brushes and blower in all the cases. Although this simple process of surface cleaning does not appear to have deleterious effects on the test results, the significance of surface preparation for proper bonding and durable structure should not be overlooked.

31. The assumption of uniform interfacial shear over the shear span of the test beam is justifiable on account of relatively large shear span (1550 mm) compared with the distance of 1400 mm between loading points. However, proper anchorage of steel should be ensured either by providing adequate bonded length or by means of mechanical devices, as mentioned by the discussers.

32. We have had a different experience with regard to the capability of ultrasonic pulse measurements to detect the condition of interface bond. Push-out test specimens for mechanical shear connectors described in reference 3 indicated much larger time-lapse readings when concrete was cast against steel section coated with mould oil than when cast against clean steel surface; mould oil was applied to some specimens in order to break the bond between steel section and concrete. It was also observed that the ultrasonic pulse measurements were irregular when the interface of steel–concrete beam (with mechanical shear connectors) was coated with mould oil.[4] Further, an increase in the pulse velocity measurements was discernible in composite beams with mechanical shear connectors and full interfacial natural bond, after they had been subjected to ultimate load tests, although no visible separation of concrete slab from steel girder was noticeable.[4]

33. Finally, we do caution about the durability aspects when using epoxy resins, despite the claims of several manufacturers in favour of their products. More data on these aspects are required, before extensive structural applications of epoxy can be recommended.

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