Adhesives in civil engineering

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Chap.1 Introduction
1.1 Definitions and bonding

- An adhesive may be defined as a material which can join the surfaces together and resist their separation.
- Structural adhesive: In this text, the term will be used to describe monomer compositions which polymerize to give stiff and strong adhesives to form a load-bearing joints.

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- There are both advantages and disadvantages so that when considering the use of adhesives the merits of the main alternative means of joining (e.g. by welding, bolting and riveting) should be assessed. (Table 1.1)
- To enhance long-term joint durability are very real.

Table 1.1 Advantages and limitations of adhesive bonding

- A: Ability to join dissimilar materials,
- L: Surface pretreatment normally required.
- L: Poor resistance to elevated temperature and fire
- A: No need for naked flames or high energy input
- L: Toxicity and flammability problems with some adhesives
- L: long term durability is often uncertain

1.4 Engineering applications of adhesives

- Aerospace: To replace mechanical fasteners with adhesives stems from desire to prolong aircraft life and to reduce costly maintenance.
- Over 50% of the airframe of modern military aircraft may be carbon fiber reinforced plastics (cfrp) with adhesives.
- Where operating temperature range is -80 to +80C, and salt spraying conditions may be severe.

Building

- Some examples include:
- Resinous grouts for anchoring bolts, ties.
- Joining and attaching internal building panels and elements
- Attachment of brick slips to concrete
- Joints between precast concrete units

Civil engineering

Whist unsaturated polyesters, polyurethanes and acrylics all have their place among the applications for thermosetting adhesives, epoxy resins remain the major candidate materials essentially in non-structural situations such as:

(1) Industrial flooring in the form of either pourable self-leveling or trowelled filled compositions.

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- (2) water-proofing membranes on concrete bridge decks
- (3) skid resistance layers on roads and other surfaces
- (4) resin mortars or concrete (for repair, etc.)
- (5) low viscosity formulations for the injection and sealing for cracks

Cont.

- (6)bonding new concrete to old
- Etc.,

Adhesives in semi-structural manner

- (11) wire, rope or strand anchors
- (12) steel fixings in concrete or rock
- (13) self-leveling epoxy grouts for the support of heavy machinery
- (14) segmental precast PC structures such as bridges, in which epoxides have been used for nearly 30 years as a stress distributing water proof medium in joints

Adhesives in a structural sense

- (15)'glulam'（a casein(カゼイン) adhesive bonded arch)
- (16) bonded external plate reinforcement for strengthening existing concrete structures
- (17) bonded composite steel/concrete decks
- (18) structural steel work connections

1.5 Relevance to civil engineering

- Unlike motor cars, civil engineering structures are not generally mass produced.
- Far lower levels of dimensional precision would also be anticipated in construction. (adhesives often are used in thick lawyers.)
- Manufacturers have naturally tailored their products to the need of aerospace and general manufacturing industries.

- Thus products developed specially for bonding steel and concrete are few.
- Many civil structures are designed for lives excess of one hundred years.
- For primary structural connections this will be the design life of the structure.
- If the bond is deteriorated, repair or strengthening may be available.
- The ability to check the integrity of bonded joint is very important. No good methods are existed.

1.6 Closing Remarks

- The more wide spread application of adhesives to bonding civil engineering structures remains both a matter of time and a matter of example.

Adhesive classification and properties 2.1 Engineering and non-engineering adhesives

- Adhesive may be classified as either organic or inorganic materials.
- Table 2.1 gives a broad classification of the organic adhesives based upon origin under general headings of animal, vegetable, mineral, elastometric, thermoplastic and thermosetting adhesives.

- The cyanoacrylates (シアノ系アクリル樹脂) are only part of the wider range of acrylic adhesives now on the market. ---- Nevertheless, the acrylics show potential for providing an alternative source of structural adhesive to epoxy resin in the future, less toxic.
- The epoxies and polyesters, together with acrylics, polyurethanes and synthetic polymer lattices will be discussed.
- Epoxy resins have several advantages.

Advantages of epoxy resins for civil Engineering Use

- 1. high surface activity and good wetting properties（濡れ性状) for a variety of substrates
- 2. may be formulated to have a long open time（固まるまで若干動いてもOK）
- 3. high cured cohesive strength: joint failure may be dictated by adherend (concrete) strength
- 4. may be toughened by the inclusion of a dispersed rubbery phase

- 5. lack of by-products from curing reaction minimizes shrinkage and allows the bonding of large areas with only contact pressure(反応で副生成物がない)
- 6. low shrinkage compared with polyesters, acrylics and vinyl types; hence residual bondline strain in cured joints is reduced
- 7. low creep and superior strength retention under sustained load
- 8. can be made thixotropic for application to vertical surfaces

- 9. able to accommodate irregular or thick bondline
- 10. may be modified by
- * selection of base resin and hardener , application of other polymers, addition of surfactants, fillers and other modifiers

- Relatively expensive
- No alkaline

2.2 Generic classification of adhesives

- Epoxy resins
- Fig.2.1 chemical structure of DGEBA
- Table 2.2 A general categorization of epoxy resins
- （Di-Glycidyl-Ether-Bisphenol”A”
- Epoxy hardeners
- Table 2.3 Hardeners for epoxy adhesives
- aliphatic polyamines and etc.

- Epoxy additives
- 1. Fillers: often simply reduce cost although they may also assist in gap filling, reduction of creep, reduction of exotherm, corrosion inhibition and fire retardation. In general fillers are inert materials which may be organic or inorganic.
- 2. Diluents: These are generally incorporated to reduce the viscosity in freshly mixed adhesive to offset the effect of the filler

- 3. Flexibilisers: They are long chain molecules which may either cause a mechanical plasticising action or react to some extent with the resin during cure to increase flexibility.
- 4. Toughеners: Unmodified epoxy systems tend to be strong in shear, compression and tension but brittle when cleavage or peel forces are imposed (Fig.2.2). Toughening is achieved by the inclusion of a dispersed rubbery distortable phase within the load bearing glassy matrix of the adhesives (Fig.2.3a).

- 5. Adhesion promoters: Sometimes referred to as coupling agents. These additives have the ability to enhance resin adhesion to surfaces such as glass or metals. The most popular type are silanes which can either be mixed with the adhesive itself or applied to the substrate or as a primer.
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- Never treat “epoxy resin” same, so many kinds are manufactured.

Fig.2.4

- Whereas in epoxies the ‘hooks（主部）’ are provided by the resin and the ‘eyes（架橋部）’ by the hardeners, in polyesters both are located in the unsaturated resin (Fig.2.4).
- The addition of a curing agent or catalyst based on organic peroxide initiates the chemical reaction and promotes cross linking within the resin
- Unfortunately, with polyester resins the contradiction during cure can be as high as 10% by volume.

- Nevertheless, they may be useful materials if a very rapid gain on strength is required from a material with a reasonable usable life after mixing.
- Several formations also have the advantage of being able to cure in sub-zero temperatures.

Acrylics

- Compared with polyesters they are a relatively recent addition to the range of adhesives potentially suitable for structural joints.
- Capable of filling up gaps up to 5mm in thickness with a usable time of between 10 and 60 minutes.
- In the unmixed versions the hardener is applied as a thin film to one of the surfaces to be bonded. The monomer is then applied to the opposite surface.

- The polymerisation starts immediately after the adhesive touches the hardener and requires about 15-20 minutes before the bonded joint can be handled.
- There are many shortcomings compared to epoxies.
- Inflammable, oxygen can be an inhibitor,
- The best acrylics attempts to overcome these.

Polyurethanes

- Uses are wide-ranging, taking advantages if strength in automotive panel bonding, through to flexibility and toughness required in shoe manufacturer.
- The bonding of highly alkaline substances such as concrete is not advised.
- End of this topic