Concrete Repair Systems: Field Performance of Pile Foundation

Dr. Mahipal Burdak

Structural Consultant Engineer, Dara Construction Company Jodhpur, Rajasthan, India

Abstract: ***The concrete structures are built keeping in mind the strength aspect. The long term durability is normally sidelined. The situation has been complicated by some types of aggressive action like Sulphate attack, abrasion, frost action, Alkali Silica Reaction (ASR), corrosion due to carbonation & chlorides, etc. The impact of these effects on structural performance & strength is less well defined; researchers have tended to take a general approach based on risk analysis & probabilistic methods. The basis for rational decision making is not clear. Is the priority to prevent or at least slow down the deterioration rate or is it to repair, upgrade, strengthen or rebuild? What is the most effective action & when should it be taken to optimize the balance between Whole Life Costing (WLC) & maintenance of satisfactory technical performance? In response to this need, the development of repair & preventive measures has become a growth industry. Quantified feedback on the performance of concrete repair systems is inadequate. There exist various individual case studies involving damage assessment & giving reason why a particular remedial action was selected. However, it is tough to have any general guidance or even a common denominator to assess alternative options. Owner's attitude appears to be vital, as indeed is cost, in the absence of quantified data. In this paper, an attempt has been made to review the work carried out by researcher Tilly in connection with the field performance of repair systems for bridges & other structures in European countries. The repair systems included: patch repairs, coatings, crack injection, sprayed concrete, electro-chemical & strength restoration. It is difficult to deduce any generally acceptable life expectancy while adopting a particular repair system. This shows that available guidelines, while improving all the time, are either not being applied properly or are still deficient in some areas.***

Keywords: Quantified feedback, deterioration, poor workmanship, incorrect design, etc

1. Introduction

Pile foundations are the part of the structure which transfers the load of the super structure to the hard bearing strata below ground surface and which resist vertical, lateral and uplift load. Pile foundations are beneficial where soil is not having adequate bearing capacity, to resist the horizontal load, for work over water eg. Jetties or bridge piers are cheaper than any other compared ground improvement costs. Piles are used for the support of bridges, buildings, docks and other structures. Mainly the materials used for pilling are wood, steel and concrete. But some difficult geotechnical condition and particularly for seismic retrofitting of structure or bridge foundation micro piling are best compare to pile foundation.

In connection with the perceived growth potential, different repair & remedial systems have evolved with new formulations & techniques. This is via proprietary materials & systems, supported by laboratory research & it is only recently that any kind of practical perspective is starting to emerge, e. g. on patch repairs [1]. In parallel, consensus guidance documents began to appear on carrying out various types of repair- e.g. in the UK by the Concrete Society [2, 3 & 4], in North America by the American Concrete Institute [5] & internationally by fib [6]. These were based on research data & practical experience in implementing repairs.

The lessons learnt include:

- The need for compatibility between parent concrete & repair material in terms of strength & stiffness [1].
- The importance of good bond
- The need for electrochemical compatibility between concrete & the repair material. Many times, the exact nature of corrosion process is not well understood & the extent of the repair area is less than it should have been [7 & 8], and
- The need to see budgets & costs, which are crucial, alongside predicted performances [9].

What is really required is quantified data from the field. In his regard, a case study is interesting [10]. It consisted of a bridge in an aggressive environment where a number of various repair & protective methods were used with the effectiveness of these being assessed some 12 years after their installation. Their effectiveness was variable. The main influence was quality of preparation & installation.

2. Studies by Tilly

Tilly provided a qualitative survey of 70 case histories of bridges from 11 European countries [11]. The bridges were built between 1908 & 1990s, with some sort of repairs in place for up to 33 years. These results were also compared with 140 case histories of other structures including buildings, dams, car parks, power stations & industrial structures. Figure 1 shows the numbers of each type of repair.

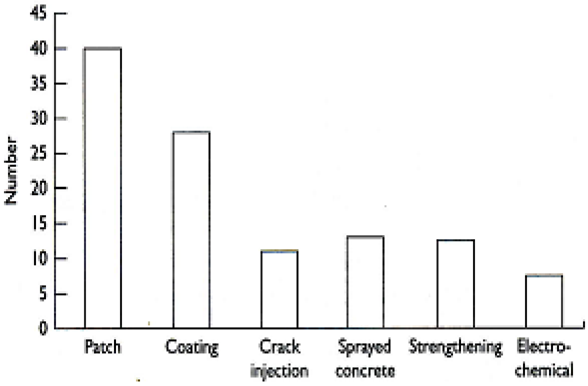

Figure 1: Types of repair- Tilly (Reference 11)

3. A 3-Level Classifying System Was Used As Below

Table 1: A-3 Classification

S N	Class	%
1	Successful; no signs of deterioration	45
2	Some evidence of deterioration (minor cracking or discoloration of coatings), but not necessarily requiring remedial action	25
3	Failure, clearly requiring remedial action	30

Above table shows the percentages in each class for the bridges. For the other structures, the trend was same, with 22% failures & 53% successes. This general data is broken in to details in figure 2.

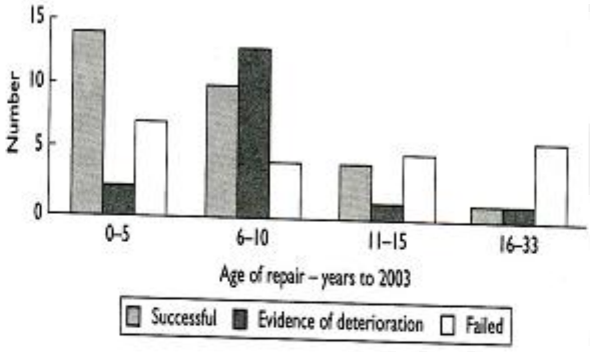

Figure 2: Classification of Performance versus Life of Repair- Tilly (Reference 11)

80% of the repairs were satisfactory for up to 5 years, 30% were satisfactory for up to 10 years & 5% were satisfactory for up to 25 years. The other structures category also reflected these figures closely. The principal modes of repair failure are shown in figure 3. Continued corrosion, cracking & debonding applied to both patch repairs & coatings.

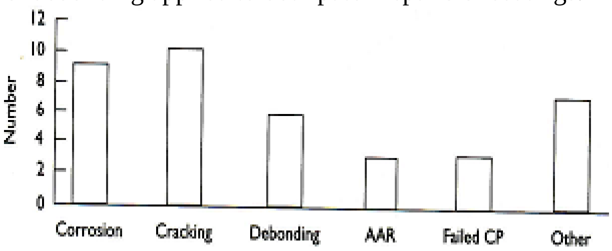

Figure 3: Reported modes of repair failures- Tilly (Reference 11). CP= Cathodic Protection, AAR= Alkali Aggregate Reaction

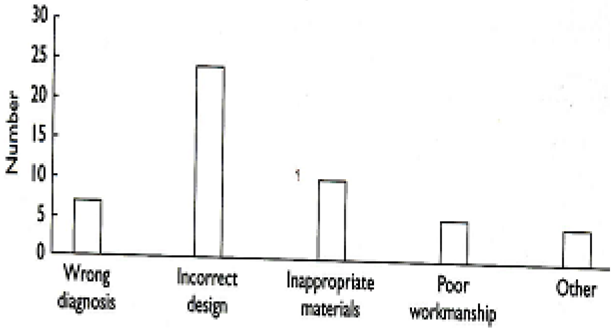

Figure 4: Failures of Repairs

Figure 4 depicts the failures of repairs due to identifiable causes [11]. In some cases, more than a single cause was identified, with incorrect design of the repair & application method being associated with poor workmanship.

The case studies presented by Tilly are very vital as they relate to performance in practice rather than in a controlled laboratory conditions. They also show the relation between diagnosing the nature & extent of the deterioration to the repair process itself, including its subsequent inspection.

4. Repair Application Model Result at Laboratory

Testing of beam Repaired with FSCC 25, loaded up to first crack appears on the surface, the testing results are as per table 4.106.

Table 2: load deformations of the beam I after repair with FSCC

S. No	Load (Kg)	Deformation (mm)	Remark
1	500	0.49	No crack
2	1000	0.47	First crack appear
3	1500	1.11	No crack
4	1800	1.77	First crack appear

(A) The another set of beams were tested for the durability study:

To study the effects of durability to the strength of the structural elements, set of the beams was casted and put into the higher salt concentratio320%) with temperature ranging 60 to 70 0C. Then one set was tested for the strength and another set was repaired by the FSCC 35 and cured and tested for the strength evaluation.

Table 3: load deformations of the beam II (after durability cycle)

S. No	Load (Kg)	Deformation (mm)	Remark
1	500	0.065	No crack
2	1000	0.188	No crack
3	1500	0.333	No crack
4	2000	0.454	No crack
5	2600	1.615	First crack appears

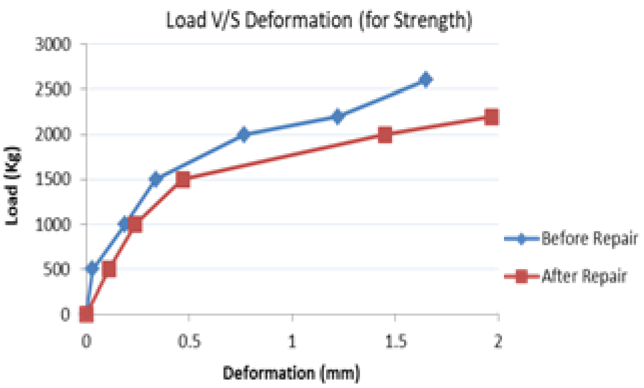

Figure 5: Load Deformation Curve of Beam Element

5. Discussions & Conclusion

The data presented in figures 1, 2, 3 & 4 show large scatter, with 20% of the repairs falling in the first 5 years & some still being effective after 33 years. It is not easy to deduce life expectancy- something that an owner would be looking for, while making a decision of adopting a certain repair system.

After evolution of the experiment tests results, the results were analyzed for comparative study of the normal conventional concrete with self-compacting concrete and Fibrous self-compacting concrete. Based on his extensive research work, Tilly suggested:

- More attention to investigate & diagnose the real cause of the distress- its nature & extent;
- Independent checking of the complete design process for the repair to ensure both aptness & compatibility;
- Close supervision of the field repair work;
- Frequent use of NDT both in acceptance testing & subsequent inspections;
- Imparting better training to operatives, especially in design, to make sure that procedures are well understood.
- The beam made of NC25 first tested up to first considerable crack to evaluate the actual strength. Initially the total load 2600 kg with the maximum deformation of 1.77 mm. After removing the cracked surface, the beam was repaired with the FSCC35, and then after the beam was again tested for the same the maximum deflection is 1.615mm.
- The beam repaired with the FSCC35, tested for load deformation again and the maximum deflection is 16.2% lower over the initially tested. The total load for beam repaired with FSCC35, is 39% lower than the internally tested.(68% strength regain)

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