The Construction and Performance of Concrete Pavements Reinforced with Flexarm

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INTRODUCTION

Continuously reinforced concrete pavements (CRCP) have been constructed in the United States for many years. In fact, the first experimental CRCP was constructed 70 years ago on the Columbia Pike near Washington, D.C., and carried traffic for over 18 years. Further construction of experimental CRCP, notably in 1925 (Public Roads Administration), 1938 (Indiana), 1946 (Illinois), 1947 (New Jersey), and 1951 (Texas), considered the influences of the percent of steel and thickness of the slab, and helped to refine the techniques associated with the design of these pavements. These study sections, and additional insight gleaned from experiences with pavements constructed in California, Maryland, Pennsylvania, and Mississippi in the late 1940's and early 1950's, helped to make continuously reinforced pavements an accepted pavement type to carry heavy highway loadings in the United States.

Despite this history of successful performance, CRCP was only introduced in Europe in 1967, on a project on the Belgian Motorway (1). However, since then, its use has grown to the point where continuously reinforced concrete is a widely used pavement type in at least Belgium, France, Italy, and Spain. It is especially popular for use on new roadways intended to carry heavy loads, or for unbonded overlays.

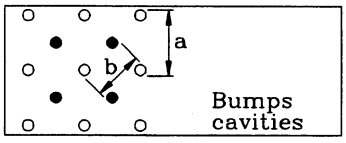
The first CRCP project in France was a reconstruction project by the Paris-Rhine-Rhône Motorways Company (SAPRR), a semi-public toll authority, on the A6 southeast of Paris, in 1983. CRCP was first used in new construction by COFIROUTE, also a semi-private toll authority, in 1986 on the A71, just south of Orléans. The use of CRCP in France has since grown to include more than 20 projects during the period from 1985 to 1991, involving both pavement widenings and new construction. SAPRR has also made extensive use of CRCP, including both reconstruction projects, new construction, and unbonded overlays.

In the application of CRCP in France, a number of problems have been encountered. One of the major concerns is that the layout and the fastening of the reinforcing bars requires a very long work train. The logistics of such a work site can be cumbersome and complex, and occasionally have been considered as a drawback to the selection of continuously reinforced pavements as the alternative of choice.

Development of Flexarm

In the mid-1980s, the French began working on solutions to some of the difficulties that they were experiencing with CRCP construction sites. The result of one of these efforts was the development of Flexarm steel reinforcement in 1985. For the first time, a reinforcing steel was available which shortened the effective work zone, eliminated the need for frequent lap joints, and allowed a reduction in labor at the work site.

Initially, Flexarm was produced as a pavement reinforcing steel, produced in a flat ribbon, 0.08 in thick by 1.57 in wide (2 x 40 mm), referred to as "slotted steel strips." The yield stress of this steel was 100 ksi (690 MPa). The top and bottom surfaces of the steel strips are deformed in a regular pattern of alternating bumps and dimples, and both surfaces are heat galvanized (see figure 1). Since the galvanization



a=0.48 inch (12mm)
b=0.33 inch (8 to 9mm)
Cavities of the one face are bumps of the second and vice versa
Depth: 0.011 to 0.013 (0.3 to 0.4mm)

Figure 1. Flexarm steel section.

takes place while the steel is still in large rolls, after the steel is cut into strips the sides of each strip are not galvanized.

Flexarm is now produced in 1.73-in (44 mm) wide strips, 0.085 in (2.1 mm) thick, with a yield stress of 115 ksi (790 MPa). It is supplied in long rolls or spools, ranging in length from 820 to 1320 ft (250 to 400 m). Because of its high strength, the steel can be stored in coils. The inner diameter of the coil is never bent to the point that its elastic limit is exceeded. Thus when the coils are unrolled, the steel lies perfectly flat.

During the period from 1987 to 1991, Flexarm has been used in a variety of projects, including a two-lane new construction project (A71, south of Orléans), several two-lane overlay projects (on A6, near Dordives), a lane widening project (A10, north of Orléans), and several three-lane overlay projects (also on A6, south of Beaune) (2).

This paper presents the preliminary results of a field evaluation of the performance of several pavements in France that used both conventional and Flexarm reinforcement. Observations from an ongoing CRCP construction site in which Flexarm was used are also presented. Because the reinforcing in these pavements is quite different from conventional reinforcement, some introductory CRCP design concepts are discussed first.

DESIGN OF CRCP

In order to better understand how the design of CRCP longitudinal steel might apply to the use of Flexarm, it is first necessary to briefly consider the design of conventional CRCP. The two major aspects of CRCP design are the required amount of longitudinal steel and the thickness of the slab. In most cases, because the reinforcing steel is not considered to provide structural support to the pavement, slab thickness design for CRCP is no different than that for jointed concrete pavements. Thus thickness design is performed using the same methods as those used for other portland cement concrete slabs. There are a number of methods currently available, including those developed by the Illinois and Texas Departments of Transportation, American Association of State Highway and Transportation Officials (AASHTO), Associated Reinforcing Bar Producers (ARBP), and the Corps of Engineers.

The design of CRCP longitudinal steel is somewhat different. The only built-in discontinuities in CRCP are the construction joints created at the end of a day's work. However, fine transverse cracks are created due to volume changes in concrete during curing or due to low temperatures (3). These cracks must be held tightly together in order to maintain structural continuity (load transfer) and to prevent the infiltration of moisture and incompressibles. The purpose of reinforcing steel is to create the cracks at regular intervals, and then to hold together the cracks that occur. Therefore, the objective of most steel reinforcement design procedures is to determine the appropriate amount of longitudinal steel (usually expressed as a percentage by slab cross-sectional area) to obtain the desired crack spacing, crack width, and steel stress.

The most frequently cited limiting values for crack spacing are a range from 3.5 to 8 ft (1.1 to 2.4 m), although McCullough proposed a range of 5 to 8 ft (1.5 to 2.4 m) (4,5,6). Lower crack spacings create a beam effect in the intact sections, and have been found to contribute to a higher incidence of distress, most notably punchouts. Greater crack spacings, in conjunction with the associated increase in movement at the cracks, results in the loss of aggregate interlock, which contributes to spalling of the cracks, and places excessive stresses on the steel located at the crack. Eventually, this process may also lead to the development of punchouts. The relationship between crack spacing and performance is not fully explained, however. Many CRCP in Illinois have crack spacings between 2 and 5 ft (0.6 and 1.5 m) and have performed exceptionally well (7,8). Additionally, CRCP in Belgium with higher percentages of longitudinal steel (0.7 to 0.85 percent) have much shorter average crack spacings (1.3 to 2.5 ft [0.4 to 0.75 m]) and show excellent 20-year performance (9).

It is generally accepted that crack widths should not exceed 0.04 in (1.02 mm) (3,4). McCullough, however, has shown that a crack width of 0.023 in (0.58 mm) might be more appropriate, based on his findings that water flow through a crack increases at 0.01 in (0.25 mm), and that at widths greater than 0.023 in (0.51 mm) the flow increases dramatically (6). This would be especially important where corrosion of the reinforcing steel is a possibility; it is not suggested that aggregate interlock is lost at this width of opening (although this may occur at openings as small as 0.03 in [0.76 mm]). Support for the positive effect of tight cracks on CRCP performance comes from field evaluations of CRCP performance in Illinois and South Carolina, which suggest that crack widths on the order of 0.02 in (0.51 mm) are highly desirable to reduce punchouts (10,11). There is a trend within the Federal Highway Administration (FHWA) to accept the more restrictive narrow width as preferable.

The limiting criteria placed on steel stress are intended to guard against the yielding and permanent deformation of the steel. In the past, this value has

been theoretically set at 75 percent of the yield stress of the steel. However, field studies have shown that this is an overly conservative value, and have led to the development of revised criteria that take into consideration the indirect tensile strength of the concrete and the reinforcing bar diameter (12).

Almost all of the available longitudinal steel design methods are empirical in origin, based on the observation of many in-service CRCP. They assume that Grade 60 steel is used and that the reinforcement consists of round reinforcing bars. As has been noted by the leading reinforcing steel industry group, the steel amount typically ranges from 0.5 to 0.7 percent, and the value of 0.6 percent "has become somewhat of an empirical standard due to the generally good experience with this amount of steel in most areas, and applies to CRC overlays as well as CRCP (12)." Interestingly, the empirical standard in Europe appears to be 0.67 percent (9).

Do the available design procedures and limiting criteria have any significance in the design of CRCP with Flexarm steel? It is apparent that the application of U.S. design methods in conjunction with Flexarm are, for the most part, not appropriate. As noted above, without exception these methods are based on the observation of pavements constructed with round, deformed reinforcing bars with a yield stress of 60 or 65 ksi (410 or 450 MPa). Flexarm is a flat, corrosion-resistant steel with a yield stress of 115 ksi (790 MPa). In addition to the shape and strength differences, there are not yet any definitive comparisons between the bond strength of the two different types of steel, so that one can not be easily substituted for the other in a design procedure.

What is needed in order to perform a similar, empirical evaluation of CRCP constructed with Flexarm reinforcement? In the past, designs of CRCP with Flexarm have also been empirical, based on the limited construction of experimental pavements and observation of the subsequent performance of the in-service pavements. Test sections were constructed in France with 0.2, 0.3, and 0.4 percent steel, and through observations it was determined that a value between 0.3 and 0.4 percent steel produced the generally recommended crack spacing and width (2).

A complete approach would consider the occurrence of CRCP failures, based on variations in the design, and under a variety of conditions. These might include a change in the percent steel and steel depth, slab thickness, ambient temperatures during concrete placement, and exposure to the different climatic zones and traffic levels. While a body of data is being collected on crack spacing and width on pavements with Flexarm, to date there have not been any failures.

According to Won *et al*, in CRCP the distress types to observe are: punchouts; crack spacing; fatigue, low temperature, and shrinkage cracking; and steel rupture (12). Delaminations due to high steel or corrosion of high steel have also frequently occurred and should be noted. These distresses are then related to the oft-cited parameters of crack spacing, crack width, and steel stress. However, the authors note that "the crack spacing is more related to the ratio of bond area to concrete volume, hereafter referred to as Q, than to [percent] steel reinforcement alone." The parameter Q was also shown to correlate better with crack width than the percent steel, and it was therefore considered to be a better input for CRCP design. It was also recommended that coarse aggregate types be considered in the design process (because of their effect on concrete properties that affect crack development) and that designs be developed in consideration of the regional environmental effect. The bond area, which is defined as the total perimeter of the steel per unit cross-section, also figures prominently in the most recent FHWA technical guidelines regarding CRCP (14). These guidelines recommend a minimum bond ratio of 0.03 in^2/in^3 (1.18×10^{-3} mm^2/mm^3) of concrete.

A cursory consideration of the bond area concept as an input to design shows that Flexarm may indeed provide a key performance benefit. Consider the steel design for a 9-in (229 mm) thick slab, 24 ft (7.3 m) wide. If the amount of reinforcement were designed to be 0.63 percent, one possible longitudinal steel design could include 37 #6 bars. The equation for Q is shown below, and can be applied to this trial pavement.

$$Q = \frac{n \times P_s \times L}{W \times t \times L} \qquad \text{(Eqtn. 1)}$$

where:

Q = ratio of bond area to concrete volume
n = number of bars per cross-section
P_s = perimeter of one bar, in
L = unit length (1 in)
W = width of the slab, in
t = thickness of the slab, in

Performing this calculation with the conventional steel results in the following:

$$Q = \frac{37 \times 2\pi \times 3/8 \times 1}{24ft \times 12\ in/ft \times 9\ in \times 1} = 0.0336$$

The same calculation of Q for Flexarm, assuming 0.34 percent reinforcement, or 71 strips, gives the following results:

$$Q = \frac{71 \times 2 \times (0.079 + 1.575) \times 1}{24 \times 12 \times 9 \times 1} = 0.09$$

Thus, for roughly half the cross-sectional amount of steel, the bond area is almost three times greater (while the yield strength is almost twice as great).

EVALUATION OF EXISTING PROJECTS

As part of an evaluation of the applicability of the French CRCP experience to U.S. practice, several CRCP projects in France were evaluated. These included pavements constructed with both conventional and Flexarm reinforcement. All of the projects were located in an area within 100 mi (160 km) of Paris, toward the south. The evaluations were cursory in nature, consisting of an estimate of the crack spacing, crack width, and macro-level observations of the pavement condition. These evaluations, which took place during September 1991, were performed in the company of representatives of the highway agencies and the manufacturers of Flexarm. The results are summarized below.

The first section visited was a portion of the A71, between Orléans and Bourgues. This project, which was the first in which CRCP was used for new construction in France, was constructed in 1986 and is 6 mi (9.7 km) long. The pavement consists of a 7.9 in (190 mm) CRCP, placed on a 2-in (51 mm) asphalt concrete (AC) bondbreaker layer, and 14 to 16 in (356 to 406 mm) of cement-treated aggregate. The steel is conventional deformed bar reinforcement, at approximately 0.67 percent. Traffic is estimated at 13,000 vehicles per day (vpd), with 12.5 percent heavy trucks. It should be noted that in France the allowable legal single axle load is 28,600 lbs (13 metric tons), and this is considered by knowledgeable engineers to be the minimum at which trucks operate.

The observed crack spacing on this project was approximately 3.3 ft (1 m), and cracks were approximately 0.02 in (0.51 mm) wide. Some minor (micro-level) spalling was observed at some of the aggregate. The surface macrotexture, created by a "chemical brushing" technique, is much different than that found in the U.S., however. The resultant coarse surface made it difficult to follow fine cracks.

At a second stop within the same section, the cracks were a little tighter, perhaps 0.01 in (0.25 mm) wide, and were more closely spaced. The average spacing was 2.0 to 2.5 ft (0.61 to 0.76 m).

The second pavement section was a Flexarm project, further south on the same section of A71, also in the southbound direction. It was constructed during March-April 1989. It also consisted of a 7.9 in (200 mm) CRCP, but it was reinforced with 0.31 percent Flexarm. The CRCP was placed on 2 in (50 mm) of AC, 12 in (300 mm) of cement-treated sand (4 percent cement; two kinds of sand), and 20 in (508 mm) of untreated aggregate. The shoulder is jointed lean concrete. Traffic on this section is 6,000 vpd per direction, of which approximately 10 percent are trucks.

On this section, the crack spacing ranged from approximately 6.5 to 13 ft (1.98 to 3.96 m), although the average was about 8.2 ft (2.5 m). The crack widths ranged from 0.01 to 0.03 in (0.25 to 0.76 mm). Some spalling of the cracks was noted on this section.

The next section evaluated was a 1990 CRCP project on the A6 in the northbound direction. The pavement is part of the SAPRR road network. It consisted of a 7-in (178 mm) thick, Flexarm reinforced overlay over California-style jointed plain concrete pavement (JPCP), on which it had been attempted to break the slab into 3.3 ft^2 (1 m^2) pieces. The base consisted of 10 in (254 mm) of broken JPCP on 6 in (152 mm) of CTB. The steel reinforcement was 0.302 percent. Flat drains were placed under the lane/shoulder joint with a shoulder outlet. Daylighted french drains were placed at 82 ft (25 m) intervals, although none could be found in the section visited. The crack widths on this section ranged from 0.03 to 0.05 in (0.76 to 1.27 mm), and the crack spacing averaged about 7.2 ft (2.2 m).

The fourth site visited was another part of the A6 project; all design features were identical. On this section, there was a noticeable dark staining in the outer 2 ft (0.6 m) of some of the cracks, at the low end of where the pavement slopes to the outer edge. A bituminous surface treatment was placed between the CRCP overlay and the original JPCP, which could be stripping and losing material through the cracks. The traffic on this section is 18,000 vpd, with 27 percent trucks. This section showed the same typical crack spacing as the previous one, and crack widths ranged from about 0.02 to 0.05 in (0.51 to 1.27 mm). It is expected that the average crack spacing and crack widths will reduce slightly in the next year.

The final project visited was constructed in 1986, and used 0.67 percent reinforcement, consisting of conventional deformed steel reinforcing bars. Otherwise, it was similar to the preceding two projects, except that the aggregate had a top size of 1.6 in (33 mm), rather than the 0.8 in (20 mm) of the previous pavements, and the aggregate was of a different gradation and type. The crack spacing on this project was 2.0 to 4.0 ft (0.61 to 1.22 m) and the crack width was between 0.01 and 0.02 in (0.25 and 0.51 mm).

Table 1. Performance summary results.

Project	Date Built	Age at Survey, yrs	Slab Thickness, in	Reinforcement		Average Crack Spacing, ft	Crack Width, in
				Type	% Steel		
A 71	6/86	5	7.9	Conv.	0.67	3.6	0.01 - 0.02
A 71	1989	2	7.9	FLEX (100 ksi)	0.30	8.2	0.02*
A 6	10/89	2	7.0	FLEX (100 ksi)	0.30	7.2	0.02 - 0.03*
A 6	10/87	2.5	7.0	Conv.	0.67	5.5	0.01 - 0.02
A 6	3/86	4	7.0	Conv.	0.67	3.4	0.01 - 0.02

* Some crack widths up to 0.05 in (1.3 mm) were noted.

1 in = 25.4 mm
1 ft = 0.3048 m
1 ksi = 6.9 MPa

Performance Summary

The overall performance of all of the projects visited was quite good. The designs are quite different, however, in the amount of longitudinal steel that they contain, and the shape and yield strength of that steel. Nonetheless, there was no discernible difference in the quality of the ride between any of the sections. While there did appear to be a difference in crack spacing and crack width between the sections with conventional CRCP reinforcement and those with Flexarm, further study is needed to identify the significance of this difference. There was a difference in age of several years between the sections with round steel and those with Flexarm, and as transverse cracks continue to develop for the first 3 years of the pavement's life, it would be difficult to compare these different sections. The results from these evaluations and further surveys performed in late 1991 are summarized in Table 1.

In the summer of 1992, as part of the European tour of concrete pavements (U.S. TECH), several of these same pavements were viewed. Observations from that study were that "the crack spacing was longer than usual and some of the cracks were spalling and had opened slightly (9)." This is of concern, especially for its potential effect on long-term performance. One possible explanation is the low percentage of steel, as in a similar section with 0.34 percent instead of 0.30 percent, the pavement had closer crack spacing, tighter cracks, and no spalling.

Another factor to consider in the analysis of crack spacings is the rate of development of cracks during the early life of a CRCP. SAPRR has been monitoring crack spacing on their A6 pavements since 1983, and their data show a significant reduction in crack spacing in the early years following construction. This is shown in Figure 2, where data from nine different Flexarm sections are plotted. While these sections represent a range in reinforcement percentage and other construction variables, it is clear that the average crack spacing decreases significantly, especially on the sections that initially had longer spacings.

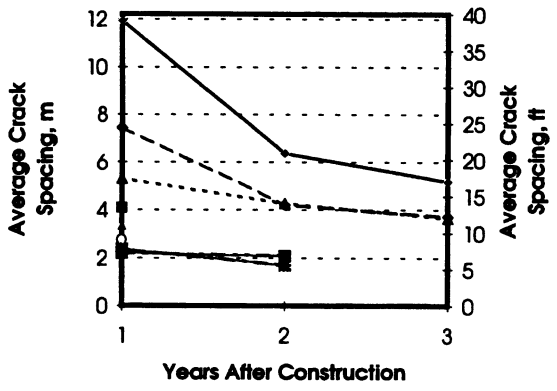


Figure 2. Relationship between average crack spacing and number of years after construction.

CONSTRUCTION WITH FLEXARM

The second part of the evaluation of Flexarm consisted of a visit to a current construction site. The site in question is on the A6 near Courtenay, and is part of a heavily trafficked route heading south from Paris. The work is a continuation of a project which was started in 1990. Work was commencing in September because the summer is not a prime construction time on many French roads due to the high volume of holiday travel that takes place at that time.

There were several interesting pieces of equipment on the work site that are not typically found at a construction site in the U.S. Starting behind the paver, where typically might be found a piece of equipment to apply the surface texture and spray curing compound, a piece of equipment was found that applies a chemical for the brushing process and places the polyethylene. The final surface is obtained by applying this chemical treatment after the paver and covering the entire pavement with plastic. After 24 hours, the plastic is removed and a power brush is run over the surface. The brush removes some of the cement at the surface and leaves a very rough macrotexture. The chemical that is applied is a retardant and it appears to primarily consist of molasses. They also use a certain percentage of porphyritic aggregate (igneous rock or rock with large feldspar crystals) to provide a durable, wear-resistant surface.

The paving equipment is fairly standard. However, immediately in front of the slipform paver was an old paver that had been converted to hold the rolls of steel strips. This is connected to the paver so that they move together. In front of the steel supply is the concrete delivery system, where the concrete is placed and fed by conveyor belt over the steel cassettes and into the slipform paver. The steel is fed into the concrete through tubes, preferably at a slight angle. The angle, approximately 1:5, helps to ensure that there is no concrete consolidation problem beneath the steel. Because of the number and width of strips needed when Flexarm is used, the steel is not all placed in one plane. Typical plan cross-sections show the steel alternating 1 in (25 mm) above and below the neutral axis of the slab. At the end of a roll of steel, the next roll is spliced with an overlap of 10 in (250 mm). This is facilitated by predrilling of the ends at the factory. As with conventional reinforcement, the splices are staggered.

Further ahead on the project is a large crane, which is used to pick up the cassettes of steel and place them on trucks to be transported to the paving operation when needed. The crane is also required to take the cassettes off of the truck and place them in their appropriate location in the paving train. The crane is not considered an extra piece of equipment, as a crane is required to be on the site anyway, in order to replace the slipform paver's power supply in case of an emergency.

The paving appears to go smoothly, with the only delays coming when the rolls of steel need to be changed. This is a process that takes 15 to 35 minutes. Some of that time is taken up by the riveting together of the existing and the new steel and some by the changing of the steel cassettes. To change the steel, after the empty cartridges are removed and the new ones are put in place, the ends of the steel ribbons are pulled through openings in their support and put in place for attaching. Figure 3 presents some of the construction details.

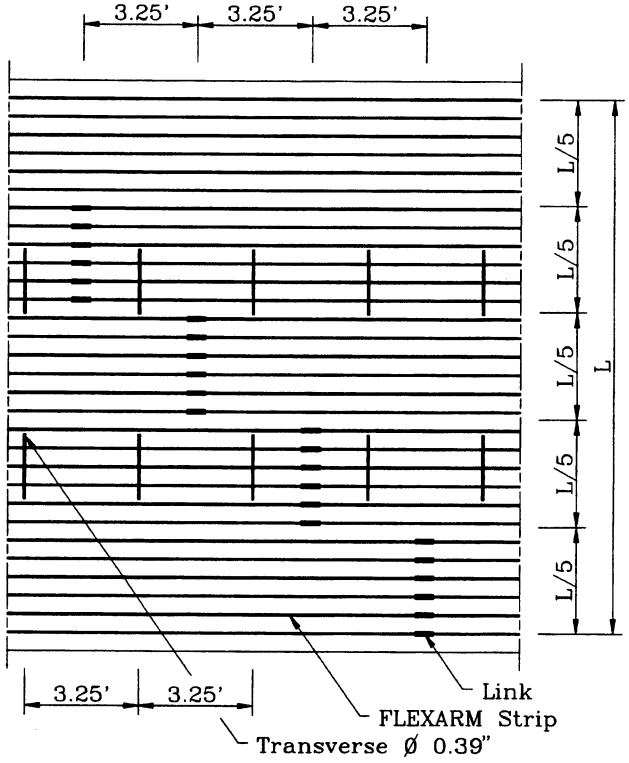


Figure 3. Typical Flexarm construction details.

The typical construction crew that is familiar with the paving operation can pave over 0.6 mi (1 km)/day with Flexarm, at a 7 to 9 in (178 to 229 mm) thick slab, 26 ft (7.9 m) wide. The percent steel that is currently being used is now 0.35. This typically results in about 56 strips placed for 2 lanes.

Table 2 presents interesting data regarding the productivity of a Flexarm construction site from the

Table 2. Comparison of construction features.

Feature	Reinforcement Type	
	16 mm (#5), Grade 60	Flexarm, 115 ksi
Recommended % steel	0.67 %	0.34 %
Weight of steel handled/work day	90 US tons	46 US tons
Weight of extra steel (overlapping, chairs)	4.5 tons	0.05 tons
Typical crew size for handling and placing steel reinforcement	20 to 40	4
Length of pavement occupied ahead of slipform paver	0.6 to 1.0 mi	100 ft
Safety of job site	20 to 40 workers handling and placing steel on work site up to 1 mi long	No workers required to be in paving area; significantly reduced construction traffic
Nighttime work	Difficult due to length of job site	Not a problem
Ability to place concrete in front of paver	Very difficult	Not a problem
Traffic diversion		Approximately 1 mi shorter

1 ft = 0.3048 m
1 mi = 1.61 km
1 US ton = 0.907 Mg

French experience. In comparing crew size and material handling requirements for a CRCP site with conventional reinforcement versus one with Flexarm, it is assumed that the crew required for placing and finishing the concrete is the same in both cases. The most notable differences are in the amount of steel to be handled and the crew size required to handle that steel. This has a direct effect on safety at the job site, due to the decreased exposure of workers to the construction site. The other significant advantage that is noted at the typical Flexarm construction site is that the work zone is much shorter (on the order of up to1 mi (1.6 km) for conventional CRCP to as little as 100 ft [30 m] for Flexarm). This permits shorter traffic diversions and reduced user costs. Also, the compactness and comparatively uniform nature of the construction operation does facilitate nighttime construction with Flexarm, if desired.

FUTURE RESEARCH NEEDS

The development of an acceptable design methodology for use with Flexarm reinforcement is based on several factors. The major differences between Flexarm and the reinforcing steel used in the U.S. lie in its higher yield strength, its corrosion resistance, its surface configuration, and its shape. The differences in strength are known and can be directly compared. The galvanization process should provide Flexarm exceptional resistance to corrosion. However, in order to evaluate the corrosion resistance, the results from standard ASTM/AASHTO tests must be obtained. In the U.S. at least, many galvanized steels have not performed well, and it is unknown what the long-term corrosion resistant characteristics of this material would be. While preliminary evaluations of the performance of pavements in France may provide some insight, it must be noted that there is likely a difference in the amount and type of chlorides that have been applied to these pavements.

Furthermore, the bonding ability of Flexarm must be thoroughly evaluated, and compared with the bond strengths of conventional steel. The results from appropriate pull-out tests would be useful. Due to the empirical nature of existing design procedures, it is not possible to design a CRCP with Flexarm instead of round deformed bars in a conventional design procedure. However, there are a number of mechanistic/empirical design methods that might be evaluated with this product.

Information on the actual depth of the Flexarm steel in the slab should also be obtained and evaluated. In the U.S., a wide variation in pavement performance has been found with variations in the depth from the slab

surface to the steel. This has led many designs to call for the steel to be placed on chairs, which is one means of controlling the ultimate location of the steel within the slab. Also, performance results in this country suggest that the steel should not be placed at the neutral axis, but above it, closer to the surface. In fact, the FHWA now recommends that the steel be placed between 1/3 and 1/2 the depth of the pavement, with a minimum cover of 2.5 to 3 in (63 to 76 mm). Designs which employ this placement pattern should be constructed and their performance monitored.

CONCLUSION

Flexarm has been widely used in France for the past 3 years on a variety of construction projects. It currently appears to be the reinforcement of choice for CRCP built by France's two toll authorities. It is believed that this product has a strong potential to be successfully used in the U.S., most notably because of its high strength, corrosion resistance, and ability to contribute to a shortened work zone. It also appears to be very cost competitive with conventional steel reinforcement. Appropriate applications would include both new construction/reconstruction, as well as unbonded, continuously reinforced overlays.

Additional research is needed on the long-term performance of the various in-service pavements, and further modifications to the design of pavements with Flexarm may evolve from consideration of these pavements. The results of pull-out and corrosion tests may also have an impact on design procedures. Future designs may also consider the incorporation of additional variables, including depth of steel and percent steel in test sections. In the U.S., a national study (HPR-2(150)) of several elements of CRCP design and performance—effect of epoxy coating and crack width/crack spacing effectiveness—is underway. The results of this study should be available in 1993 and will undoubtedly shed further light on issues related to steel design and CRCP performance.

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