



## PUTTING IT ALL TOGETHER

### PERFORMANCE, TESTING, ANALYSIS, & CRITERIA FOR GFRP DOWEL BARS IN JOINTED CONCRETE PAVEMENTS

Advantages of GFRP Dowels in JCP



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# Overview of Composite (GFRP) Advantages in JCP

## GFRP Dowel Bar Research Update and Aggregation

The intent of this report is to address each major issue regarding composite (GFRP) dowel bars versus their steel (any type of steel) counterparts. Cited are Independent Testing Reports completed to date which demonstrate how each of the tests addresses the issues of GFRP dowels. Each of these test reports can be seen in their entirety on our website at [www.sigmadg.com](http://www.sigmadg.com).

There have been numerous studies and trials performed on GFRP Dowel Bars for Jointed Concrete Pavement (JCP) due to their tremendous advantage of being corrosion free and virtually maintenance free. Each study has also emphasized different performance aspects of JCP in relation to GFRP such as:

- Material Properties of GFRP
  - Glass Type
  - Resin Type
  - Durability and Strength of Different Types of GFRP
  - Resistance to Alkaline Attack and Moisture Absorption
- Relative Deflections (RD)
- Load Transfer Efficiency (LTE) or joint effectiveness
- Bar Diameter - Effect on LTE and RD
- Bearing Stress
  - Induced By Dynamic Loading
  - Induced By Environmental Factors
    - (smaller modular ratio may be more beneficial)
  - Which Has A More Significant Impact On The Life of the Joint?
- Dowel Bar Retrofit (DBR)
- Constructibility

## Summary of Titles of Test Reports

1. Fiber Reinforced Polymer (FRP) Composite Dowel Bars - A 15 Year Durability Study:  
Market Development Alliance (ACMA) - FRP Dowel Bar Team
2. Laboratory Evaluation of Fiber-Reinforced Polymer Dowel Bars for Jointed Concrete Pavements: Bian, Kohler, Harvey - TRB Annual Meeting 2007
3. Design and Evaluation of Jointed Plain Concrete Pavement with Fiber Reinforced Polymer Dowels: Publication No.: FHWA-HRT-06-106 - 2009
4. Glass Fiber-Reinforced Polymer Dowels for Concrete Pavements: Eddie, Shalaby, Rizkalla - ACI Structural Journal 2001
5. Construction and Test Results on Dowel Bar Retrofit - Heavy Vehicle Simulator: Bian, Harvey, Ali - UC Davis/Berkeley Pavement Research Center 2006
6. Owens Corning Lab Testing information off their website:  
<http://www.owenscorning.com/composites/aboutAdvantex.asp>
7. High Performance Concrete Pavements: Various Authors,  
Publication No: FHWA-IF-06-031, February 2006

# Importance of Raw Materials and the Manufacturing Processes of GFRP Dowels

## Resin Matrix

The University of California Pavement Research Center has performed extensive testing on dowel bars manufactured with different resin matrices (Polyester v. Epoxy Vinylester) and how each resin type performs under accelerated lab testing. This particular research project highlights the difference a resin matrix can have on the performance of GFRP dowel bars. This research concluded that the *Epoxy Vinylester was 20% stiffer, 80% stronger in bending, and 100% stronger in shear than Polyester bars and that both resin systems offered similar flexural fatigue performance.* Moreover, if the stress ratios are kept to 0.3 - 0.4, then more than 100 million wheel load cycles can be expected. (see bearing stress section)

## Glass Transition Temperature

The same UC study outlines the performance (stiffness) of GFRP at different temperature levels. This performance difference is directly attributed to the Glass Transition Temperature (Tg) of each dowel. Tg tells us when performance will start to drop off as the resin starts to soften at elevated temperatures. The higher Tg the better and more consistent performance at elevated temperatures. Tg is also a measure of matrix cure of the glass/resin system. In other words, *how well has the bar been cured* during manufacture to ensure the maximum achievable results are obtained. There are ASTM test methods to gather this information including, DMTA (Dynamic Mechanical Thermal Analysis) testing protocols, and the AASHTO LRFD design Guide for GFRP. Each recommends that rebar Tg be no less than 100°C.

## Glass Choice and Impact on Moisture Absorption and Long Term Performance

The choice of glass types used in GFRP systems can not be emphasized enough. Lab testing done by Owens Corning has conclusively demonstrated that E-CR glass (which is Boron Free) has a much higher degree of durability and lower susceptibility to alkali attacks than traditional E-Glass. It is critically important for the glass to maintain its mechanical strength and properties over time, and this is accomplished only through using E-CR glass that is proven to perform over the life of the structure or pavement.

This factor can be accounted for in the Moisture Absorption tests done on GFRP bars according to ASTM D-570. Currently, ACI and AASHTO recommend a moisture absorption of 1% or less. By using higher quality materials, Mateen recommends that the acceptable level of moisture absorption be *less than 0.1%* in order to maintain the mechanical properties of the glass over the long term.

This combined with an extremely strong resin matrix system (Epoxy Vinylester) combines to make a product that is extremely strong and durable. Mateen is comprised of both E-CR glass and an Epoxy Vinyl ester resin.

## Relative Deflections and Load Transfer Efficiency (LTE) of GFRP Dowel Systems

Relative Deflection (RD) of the approach and leave panels are associated with ride quality in Jointed Concrete Pavement (JCP). The less the panels deflect, the smoother the riding surface. However, there is currently no AASHTO guideline for limiting relative deflections in JCP. Instead, most states rely on Load Transfer Efficiency, or the amount the approach and leave panels deflect in relation to each other. ACPA currently recommends a LTE of 75% or greater for a properly functioning joint.

GFRP dowels has long been thought to provide higher relative deflections to a similar steel dowel configuration due to the lower modulus of the GFRP dowel. While this is true in theory, there is much more that figures into relative deflection such as: Modulus of the Sub-base Support, Concrete Strength, Crack Width (expansion / contraction joint model), Temperature, Slab Thickness, Aggregate Size / Interlock, and Load Applied on the Joint.

Additionally, it has been argued that the stiffness match between GFRP and concrete actually *aids in reducing the overall (average) stress of the system* due to the nature and composition of GFRP in relationship to concrete. In other words, the bars tend to move with the concrete as opposed to steel that provides for no movement at all. When no movement is provided by the dowel bar cracking and popping of the concrete occur, thus significantly shortening the life of the entire pavement system.

## Joint Design (Smaller Diameter & Closer Spacing) and Bearing Stress Size Matters!

### *Bearing Stress Induced By Dynamic Loading*

Bearing stress at the concrete / dowel interface often times is the limiting factor in the design life of concrete pavements. When stresses at this interface become too great, the dowel sockets, and LTE, is greatly diminished leading to premature failure of the joint. Some causes that lead to this type of failure are:

- Corrosion causing the steel to expand and lock the joint
- Corrosion leading to loss of effective cross sectional area and / or length
- Dowel misalignment (skewed or improper saw cut) causing the joint to lock
- Bond strength of steel dowels is too great

It is argued that GFRP causes higher bearing stress at the joint face due to lower modulus. In fact, the issue was of such a concern, there were a couple of reports which specifically address this in regards to GFRP. Some have even argued that GFRP is not an acceptable alternative due to the bearing stress issue.

In Eddie et al, 2001, their laboratory tested GFRP dowels in 10" concrete with 1.5" GFRP dowels at 12" spacing versus 1.25" epoxy coated steel dowels at 12" spacing. What they found was that these two designs had very similar results in LTE, and the GFRP dowel with the highest shear strength performed the best. It was also concluded that a 1.5" diameter GFRP Dowel was suitable for use in 10" concrete or the replacement of a 1.25" EC steel dowel in lesser concrete thicknesses. Here is a quote from their conclusion...

*"Although higher deflections are typically associated with loss of support and shorter pavement service life, this may not be the case for GFRP. In fact, the lower flexural stiffness modulus of GFRP compared to the stiffness modulus of steel and the larger dowel diameter are both advantageous in this type of application because of the **reduced bearing stresses on the concrete surrounding the dowel.**"*

Along these lines, Idaho Transportation Department (ITD) has approved and begun the largest installation of 64,500 GFRP Dowels - MATEENDOWELS - to date in the United States. ITD's design called for the same set up as the ACI test recommendations of 10" concrete with 1.5" dowels spaced at 12 inches center to center. The MateenDowels proved to be the most cost competitive dowel in ITDs non-corrosive dowel bar specification which include stainless steel, stainless clad, zinc coated, and ASTM 1035 or MMFX.

FHWA has also published a comprehensive study of GFRP dowels under **Publication No.: FHWA-HRT-06-106 - 2009**. The beginning of the study opens by giving a literature review of many of the reports that are published to date. The authors conclude the following from the previous published literature...

*“The literature review indicates contradictory conclusions on the LTE of 3.81-cm (1.5-inch) FRP dowels. Suggestions are also provided by the researcher to increase dowel bar diameter from 3.81 cm (1.5 inches) to 4.45 cm (1.75 inches). Some researchers have noted increased RD with an increased diameter. Hence, it was decided to utilize 3.81- and 2.54-cm (1.5- and 1.0-inch) dowel diameters in this research with 69.47 percent and 72 percent FWF, respectively.” page 6.*

The researchers also state the reasoning in using smaller diameter bars as opposed to larger diameter bars.

*“Dowels with 3.81- and 2.54-cm (1.5- and 1.0-inch) diameters were used in this project. Other researchers have commented on using 4.45-cm (1.75-inch)-diameter FRP dowel bars instead of 3.81-cm (1.5-inch)-diameter dowel bars. However, researchers have noted that increased bar diameter results in larger RD. Hence, it was decided to use lower diameter bars in this research.(9)” page 7-8.*

As the supplier and manufacturer of MateenDowel, we have first hand knowledge and testing data that smaller diameter rods do have higher relative performance numbers (tensile, shear, glass transition, and modulus) versus the larger diameter rods (1.5” and greater) to further verify this observation.

FHWA also did extensive research into the issue of bearing stress and some of their findings are below.

*“Peak bearing stress at the joint location **does not take into account the stiffness match between FRP dowels and concrete**, which allows better distribution of bearing stress leading to reduced bearing stress concentration (table 34 and table 35). Theoretical calculations indicate allowable stress is exceeded. **However, for 3.81-cm (1.5-inch)-diameter FRP dowel bars with 30.48-cm (12-inch)-c/c spacing, the average bearing stress is only 35.4 percent** (the distance from the joint face to the first reflection point) and 0.98 percent (within 2.54 cm (1 inch) distance from the joint face) of the peak bearing stress.” page 112*

**“For 2.54-cm (1.0-inch)-diameter FRP dowel bars with 15.24-cm (6-inch)-c/c spacing, the average bearing stress was only 34.94 percent (distance from joint face to the first reflection point) and 50.44 percent (within 2.54 cm (1 inch) distance from joint face) of the peak bearing stress (table 37 and table 38). Hence, based on stress redistribution, peak bearing stress did not appear to have damaged the concrete surface.”** page 129

**Table 37. Peak bearing stress and average bearing stress in dowel ((2.54-cm (1.0-inch) diameter at 15.24 cm (6 inches) c/c) downward area.**

Material	Maximum Deflection ( $10^{-3}$ inch)	Modulus of Dowel Support (pci)	Peak Bearing Stress (psi)	Average Deflection in Dowel Downward Bending Area ( $10^{-3}$ inch)	Modulus of Dowel Support (pci)	Average Bearing Stress (psi)	Average/Peak Bearing Stress (percent)
FRP	4.479	300,000	1,343.7	1.565	300,000	469.5	34.94
		1,500,000	6,718.5		1,500,000	2,347.5	
Steel	2.906	300,000	871.8	1.159	300,000	347.7	39.88
		1,500,000	4,358.4		1,500,000	1,739.1	

NOTE: In table 37, the downward dowel length of FRP and steel dowels ranges from 0 to 3.81 cm (0 to 1.5 inches) and 0 to 7.62 cm (0 to 2 inches)(figure 134), respectively. Values of modulus of dowel support range from 8,303.972 to 4,159.858 kg/cm<sup>3</sup> (300,000 to 1.5 million pci).<sup>(15)</sup>.

1 inch = 2.54 cm

1 pci = 0.02768 kg/cm<sup>3</sup>

1 psi = 0.006895 MPa

This finding was further evidenced by splitting the experimental slabs in half after 5 million cycles to see if any affects of bearing stress was causing undo strain or socketing on the dowel/ concrete interface.

- *images from FHWA report* -

It was concluded that the length of the dowel could mitigate the effects of bearing stress to a certain point for each type of dowel. After a certain point, the added length of the dowel has no effect on further reducing bearing stress.

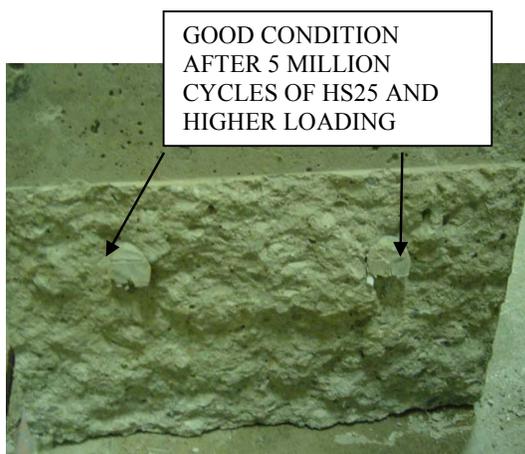
### 1" GFRP Dowels

*"The required length of 2.54-cm (1.0-inch)-diameter FRP dowels was only 69.23 percent (9/13) of the required length of steel dowels with the same diameter. Based on inflexion points (figure 109), the minimum total length for steel dowel was 33.02 cm (13 inches) (2 × 16.51 cm (2 × 6.5 inches)), whereas, for FRP dowels, the minimum length was 22.86 cm (9 inches) (2 × 11.43 cm (2 × 4.5 inches))."* page 129

### 1.5" GFRP Dowels

*"The required FRP length for 3.81-cm (1.5-inch)-diameter dowels was only 64.7 percent (11/17) of that of steel dowels with the same diameter. Based on inflexion points (figure 108), the minimum total length needed for steel dowels was 43.18 cm (17 inches) (2 by 21.59 cm (2 by 8.5 inches)), whereas FRP dowel bars needed 27.94 cm (11 inches) (2 by 13.97 cm (2 by 5.5 inches))."* page 127

It is worth noting that the calculated minimum length needed for steel is 17 inches. This means that with the current standard spec of 18 inch by 1.5 inch diameter dowels, there is very little room for error when installing steel dowel bars in concrete roads. To achieve the optimal level of bearing stress calculated, the contractor saw cutting the contraction joints has a margin of just a half inch or risks having a joint that does not function properly. With GFRP, that margin of safety error is greatly increased due to the length of dowel needed to dissipate the bearing stresses.



**A few Major Conclusions made by FHWA in this Study are:**

*“In this research, FRP dowels were found to be good alternatives to traditional steel dowels for transferring joint loads in JPCP pavements. Joints with FRP dowels provided adequate LTE, exceeding the values recommended by AASHTO (75 percent) and ACPA (60 percent) in both laboratory and field tests.”*

*“The stiffness match between FRP dowels and concrete led to comparable FRP dowel flexing under joint loads, leading to shorter FRP dowel length. The required length of FRP dowels with 3.81-cm (1.5-inch) diameter was 64.7 percent of that for steel dowels with the same diameter. The required length of FRP dowels with a 2.54-cm (1.0-inch) diameter was 69.23 percent of that for steel dowels with the same diameter.” page 130*

**“FRP dowels can be used as effective alternatives for construction and rehabilitation of JPCP under highway traffic with advantages of corrosion resistance and decreased maintenance.”**

### **Bearing Stress Induced By Environmental Factors**

An often overlooked cause of bearing stresses in JCP is the stress induced by the shrinkage of the concrete after it is installed. When JCP cures, the dowels installed in the joint often help in preventing the slabs from curling. The Ohio DOT has done significant research in this area and has their conclusions and findings published in the FHWA report on High Performance Concrete Pavement (HPCP). Their key findings are listed below.

One of their final conclusions was that GFRP dowels induced less bearing stress (from curing, shrinkage, and curling) on the joint due to the smaller modular ratio and that environmental factors must be included in the design of JCP as it may have a more significant influence on the long term performance of the joint than dynamic forces acting on the doweled joint over the lifetime of the pavement.

- In addition to transferring dynamic load across PCC pavement joints, dowel bars serve as a mechanism to reduce the curling and warping of slabs due to curing, and temperature and moisture gradients in the slabs.
- Steel and fiberglass dowels both experienced higher moments from environmental factors than from dynamic loading. The dynamic bending stresses induced by a 56.9 kN (12,800 lb) load were considerably less than the environmental bending stresses induced by a 3 °C (5.4 °F) temperature gradient.
- Steel bars induced greater environmental bending moments than fiberglass bars.
- Significant stresses were induced by steel dowel bars early in the life of this pavement as it cured late in the construction season under minimal temperature and thermal gradients in the slab. Concrete pavements paved in the summer under more severe conditions may reveal even larger environmental stresses.
- Both types of dowels induced a permanent bending moment in the PCC slabs during curing, the magnitude of which is a function of bar stiffness.
- Curling and warping during the first few days after concrete placement can result in large bearing stresses being applied to the concrete around the dowels. This stress may exceed the strength of the concrete at that early age and result in some permanent loss of contact around the bars.
- Steel bars transferred greater dynamic bending moments and vertical shear stresses across transverse joints than fiberglass bars of the same size.

*Excerpt from Page 118 of FHWA Publication #: FHWA-IF-06-031, High Performance Concrete Pavements, Project Summary*

## Dowel Bar Retrofit (DBR with GFRP)

The major study done with GFRP dowels in DBR work was performed by CalTrans and UC Davis. MateenDowels (High Performance GFRP Dowels) are being installed in 1000 feet of concrete highway on I-82 in Washington State in a DBR application. The initial results of a 3 joint trial are extremely promising and have moved WsDOT to perform a full scale test to verify the results from the first 3 joint test.

In the Heavy Vehicle Simulator: Bian, Harvey, Ali - UC Davis/Berkeley report, the researchers were primarily interested in the benefits of restoring load transfer via dowel bar retrofit techniques. They also wanted to investigate different dowel materials and see how they performed under accelerated heavy vehicle traffic.

The materials and test set up for the Heavy Vehicle Simulator test sections were as follows:

- 4 dowels per wheel path
  - Epoxy Coated Steel
  - GFRP
  - Hollow Stainless Steel Tubes
- 3 dowels per wheel path
  - Epoxy Coated Steel

*“HVS results show that for each of the DBR alternatives, load transfer efficiency was not substantially damaged by heavy HVS loading and that the slabs failed by fatigue cracking before the LTE dropped substantially. These results, where DBR outlasted the structural effectiveness of the concrete slabs, are representative of the materials, quality, conditions, and workmanship in these test sections.” page vi*

***“Comparison of DBR alternatives: LTE under HVS loads.***

*All of the sections showed a slight increase in initial LTE with increase in HVS wheel load (from 60 to 90 to 150 kN). LTE is nearly always higher than 90 percent on the DBR joints, regardless of temperature and load, under HVS loading (using the moving wheel definition of LTE described in this report).*

***Comparison of DBR alternatives: LTE after HVS trafficking (JDMDs).***

*All of the DBR joints showed little or no decrease in LTE after HVS trafficking, based on measurements under the 60 kN HVS wheel load.” page vii*

The most amazing part about this study was not that LTE of the GFRP was not diminished after repetitive heavy loading, ***but that LTE was equivalent to the other***

*dowel types despite being installed improperly.* Some of the cores that were taken show that the GFRP dowels were installed well above the mid-depth of the panel. This is further evidence that GFRP dowels provide a far superior build vs steel because of the greater allowable margin of error. The pictures taken from the Study show an intimate interface between the dowel and concrete. *There are no signs of bearing stress weakening this interface.*



**Figure 2.30. Core DBR33NE2 with hollow stainless steel dowel located 6 mm above mid-depth of slab.**



**Figure 2.32. Core DBR42NWC with FRP dowel located 62 mm above mid-depth of slab.**



**Figure 2.31. Core DBR33NW with epoxy-coated steel dowel located 12 mm above mid-depth of slab.**



**Figure 2.33. Core DBR42NNW with FRP dowel located 23 mm above mid-depth of slab.**

## Constructibility with MateenDowels

**Disclaimer: This section applies only to MateenDowels due to conclusive evidence of performance in both the lab and real world installations. Other composite products may or may not work in the same fashion.**

One of the reasons newer products fail to be readily accepted within the marketplace is because it often takes years to figure out how to use and install them properly. Contractors have to learn a new method of bidding, purchasing, delivery, and installation which is a huge hidden cost of any new product plus a large risk borne by the contractor. If new and innovative products cost the contractor added time and lost margins, the likelihood of any new product succeeding is greatly diminished, and the status quo will continue in perpetuity.

Mateen products considered this obstacle before entering the U.S. market. Our products are designed to bid, deliver, and install almost the same as other more traditional products like steel. In fact, in some situations Mateen is easier to use than steel!

### ***Types of Installation that Work Best with MateenDowels:***

1. ***Dowel Bar Insertion Machines (DBI):*** Currently, the largest composite dowel bar project ever in the history of the U.S. is being conducted in Boise, ID on 1-84. The total MateenDowels used was: 64,500 units. Of those, 46,500 MateenDowels are being used in a DBI machine (manufactured by G&Z). Those dowels are 1.5" x 18" long. Idaho Transportation Department required that since the use of composite dowels in a DBI machine was new they wanted to ensure proper depth and alignment. They required the contractor to uncover 10% of the bars (ITD's discretion which ones) to meet their requirements. The contractor could reduce that requirement to 5% once it was proven to ITD that proper alignment and depth was reached consistently. **To date, not one dowel bar was out of depth or alignment.**
2. ***Baskets:*** Sigma DG Corp has developed a way to take an existing basket design from any state and slightly modify it so that MateenDowels can be secured on the basket. Due to MateenDowels being completely non-corrosive there is no need for:
  - i. coating the basket in anyway (tectyl or epoxy)
  - ii. cutting the shipping wires to ward off corrosion of the dowel

Baskets come ready to install with the bars already in them. One only has to unload the baskets from the truck, align within the path, pin, and run the paving machine. We suggest adding two extra pins at each end of the basket that will ensure the basket does not move during paving. This work has been done extensively and it is proven that our baskets hold up under the tremendous pressures of the paving machine.

3. ***Dowel Bar Retro Fit (DBR)***: As with the baskets, our bars come ready for installation and include the chairs, caps, and foam insert. They install exactly the same as epoxy coated dowels.

4. ***Handling***: MateenDowels are handled easier than steel dowels.

- One does not need to worry about them being dropped or scratched.
- No bond breaker is required since composite dowels are much slicker than steel
- No need to reapply any other types of coatings like epoxy - composite dowels are non-corrosive throughout the bar
- If product is stored outside simply elevate off the ground (pallet) and cover with a tarp - direct sunlight for a long period of time (6 months +) yellows the bar but doesn't affect performance
- Dowels can be cut to shorter lengths by simply using a circular saw. Use a face mask, eye protection, and gloves to protect from dust particles.
- If using grout or epoxy for DBR work - use the same types as with steel dowels
- MateenDowels are completely inert - MSDS sheets are readily available

***MateenDowels come in the following sizes:***

1.5" (38mm) x various lengths

1.25" (32mm) x various lengths

1" (25mm) x various lengths

## Conclusions

1. In GFRP Dowels, shear strength is directly correlated to LTE. The higher the shear, the higher the LTE. MateenDowels have proven that they have the highest shear capacity to date of any GFRP dowel on the market.
2. The durability of GFRP Dowels has been proven through many different methods: The 15 year real world durability study, Caltrans HVS test, Owens Corning stress testing on their Advantex® E-CR glass, UC Davis/Berkeley study on Polyester vs. Epoxy Based Vinylester Resin dowels. All tests demonstrate the long term durability of GFRP Dowels.
3. Materials Matter! Bian, Kohler, and Harvey have proven that Epoxy Based Vinyl Ester (EBVE) resin is considerably stronger than polyester resin through lab tested results. Their lab results showed that EBVE resin dowels are 20% stiffer, 80% stronger in bending, and 100% stronger in shear than similar sized polyester dowels.
4. Glass selection has just as critical of an effect on long term performance. Owens Corning has shown in their lab testing that E-CR glass (which is boron free) is exponentially more resistant to alkali attack than traditional E-glass fibers.



### Advantex® and E-glasses in acid for 4 hours

This microscopic view of glass fibers in the acidic media shows the degradation of the E-glass which occurs by an etching process that involves hydration followed by total dissolution of the E-glass, while Advantex remains unharmed.

5. Size Matters! In addition to the selection of raw materials, the performance for different diameter rods are going to vary slightly. It is a generally accepted principle of GFRP that a small diameter rod will have relatively higher performance numbers than a larger diameter rod.

6. By using smaller 1 inch diameter dowels spaced closer together, the GFRP rods are more stiff than the 1.5 inch diameter dowels and provide for higher LTE and lower RD. This also moves

more surface area into the radius of relative stiffness helping the rods to act as a system rather than independently.

7. The following table is suggested for size and spacing in new construction:

<b>Slab Thickness</b>	<b>Typical Steel Dowel Design - Length = 18"</b>	<b>Suggested GFRP Joint Design - Length = 14"</b>
< 9 inch	1" or 1.25" EC Steel @ 12" c/c	1" GFRP @ 8" c/c spacing
9 - 10 inch	1.25" EC Steel @ 12" c/c	1" GFRP @ 6" c/c spacing
> 10 inch	1.5" EC Steel @ 12" c/c	1.25" GFRP @ 8" c/c spacing

8. By specifying GFRP dowels with EBVE resin and an E-CR glass combination, the predictability of high durability, strength, modulus, and low moisture absorption will give designers peace of mind when specifying composite dowels.
9. GFRP is a more forgiving concrete reinforcement material with a lower modulus that can be more beneficial to JCP due to the fact that it matches the stiffness of the concrete more closely than steel and reduces the environmental induced bearing stresses in JCP.
10. All Mateen products use the combination of EBVE resin and Advantex® E-CR glass for the most superior composite system on the market.
11. Proven results of GFRP dowels over the past 20 years in both the lab, field, and in theoretical studies, consistently show the superiority of composite dowel bars over that of any type of steel.