Adjustable haunch forms for precast concrete bridge deck systems

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- Precast concrete bridge decks that require adjustment have not been widely adopted, in part because they require manual forming to complete the construction of the haunch after the field geometry changes.
- This paper presents an adjustable forming system comprising commonly available packing foams and adhesives. Several test methods were developed to investigate the performance of these systems from different precast concrete bridge construction processes.
- The paper recommends materials to be used, along with a typical construction sequence.

Precast concrete bridge deck systems provide an effective construction technique that can be implemented for the rehabilitation of existing highway bridges as well as new bridge construction. These systems have the potential to improve both safety and speed of bridge construction.[1–3] These bridge decks are made of precast concrete members that are field adjusted before placing a reinforced concrete topping.

One drawback to field-adjusted precast concrete bridge deck systems is that they require external formwork for the haunch to be built once the final geometry has been established. The haunch, the space between bridge girder and deck, is adjusted to yield the correct roadway profile and deck thickness. Due to tolerances of member dimensions and camber, roadway geometry from vertical curves, superelevations, and cross slope, the haunch height varies over the length of the bridge. Furthermore it is almost impossible to determine the haunch geometry before bridge construction. If the haunch is not constructed correctly, it is impossible to provide a smooth riding surface. This can necessitate removal and replacement, grinding, or overlay to correct the ride of the bridge deck.

Figure 1 shows a typical cross section of the adjustable haunch forming system. Previously developed precast concrete bridge deck systems have required that the haunch be manually formed and then removed after concrete placement.[3–6]

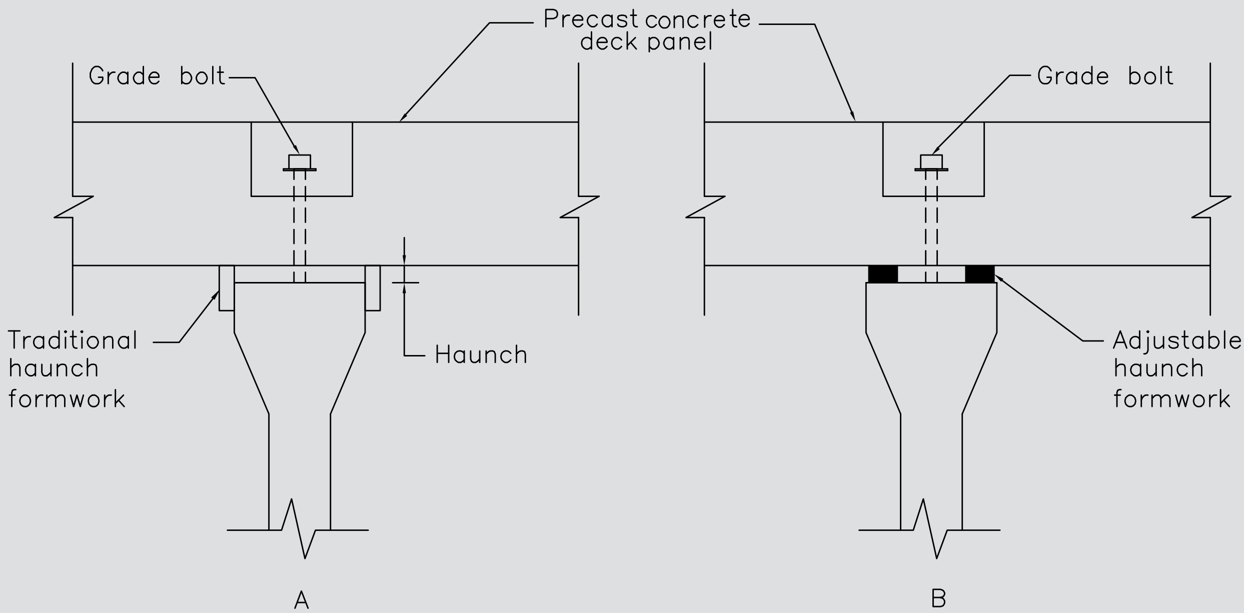

Figure 1. Typical cross section of a precast concrete bridge deck with traditional formwork and with adjustable formwork.

While this approach has been satisfactory for some projects, the cost and constructability could be improved with a stay-in-place haunch form with adjustable geometry. This form would have to resist lateral pressure from fresh concrete or grout, allow for easy adjustment, and not require workers to be under the bridge for installation or removal.

This paper presents an adjustable forming system that uses packing foam as a stay-in-place adjustable haunch form. The foam may be attached with or without adhesive. The foam-adhesive combination is easily compressed or elongated and does not absorb water. Several tests were designed to simulate the performance of this system in different phases of bridge deck construction. Based on the test results, recommendations are made for precast concrete bridge deck construction.

While the focus for this work is precast concrete bridge decks, adjustable forms comprising packing foam and adhesive would be beneficial with any precast concrete application in which the geometry is not finalized until construction.

Materials

Packing foam

Rigid foams have been used in the past with precast concrete systems that are not adjustable, such as partial-depth precast concrete panels.[3] These foams have to be cut to the exact dimensions needed and then the precast concrete elements bear on them until concrete can be placed. Because these foams are rigid, they are not able to adjust if the geometry for the precast concrete bridge deck system is changed. A material is needed that is compressible but also has memory and enough strength to resist construction loads.

Based on conversations with foam manufacturers, two different types of closed-cell foams were investigated. These foams were chosen for their durability and resistance to water absorption. A polyethylene and a cross-link foam of different densities were investigated. The polyethylene foam is produced by polymerization of ethylene and trapping air bubbles within the ethylene matrix. This material is typically extruded into sheets that can be laminated together to build up different thicknesses. The cross-link foam is similar but uses specialized polymers in combination with cross linking reagents instead of ethylene. The cross linking reagents alter the physical properties of the foam, increasing its density, strength, and stiffness. The cross-link foam is also extruded and can be laminated to form different thicknesses. Both foams are commonly used as packing materials for computer components, are economical, and are also widely available. Different densities of the polyethylene and cross-link foam were investigated because they have a significant effect on the properties.

Table 1 summarizes data on the foam properties from producer literature. These properties are typically specified when foams are used as packing materials. Foams 1 through 3 are polyethylene foams, and foams 4 and 5 are cross-link foams with different densities. Typically, as density increases so do elastic modulus and tearing resistance.

Adhesives

Next, adhesives were identified that were compatible with both concrete and the five foams. The three types of

Table 1. Summary of the manufacturer-reported foam properties

Property	Foam number					ASTM test method
	1	2	3	4	5	
Type of foam	PE	PE	PE	CL	CL	n/a
Density, lb/ft^3	1	1.2	1.7	2	4	D-3575-W
Deflection for an applied 25% axial stress, psi	3	5	5.5	5	9	D-3575-D
Deflection for an applied 50% axial stress, psi	6	10	12.5	14	19	D-3575-D
Increase in deflection from a 2-hour sustained load, %	30	30	34	n.d.	n.d.	D-3575-B
Increase in deflection from a 24-hour sustained load, %	24	24	20	n.d.	n.d.	D-3575-B
Increase in deflection for a 1 psi load, %	12	5	3	n.d.	n.d.	D-3575-BB
Tensile strength, psi	20	38	26	54.5	84	D-412
Elongation capacity, %	75	75	59	237	311	D-412

Source: PXL, manufacturer's data sheet, 2003; Pregis, manufacturer's data sheet, 2005.
Note: CL = cross link; n/a = not applicable; n.d. = no data; PE = polyethylene. 1 psi = 6.895 kPa; 1 lb/ft^3 = 16 kg/m^3.

Table 2. Summary of the manufacturer-reported adhesive properties

Properties	Type of adhesive			ASTM test method
	Synthetic elastomer liquid	Two-part epoxy	Aerosol	
Color	Light amber	Blue	Blue	n/a
Coverage, ft^2/gal.	308	320	213.33	n/a
Viscosity, mPa-s	175 to 275	n/a	n/a	n/a
Work time at 75°F, hours	0 to 1	1 to 2	8	n/a
Tensile strength, psi	n.d.	2490	n/a	D882-83A
Elongation at break, %	n.d.	31	n/a	D882-83A
Coefficient of thermal expansion, mm/mm°C	n.d.	365×10^6	n/a	n/a

adhesives investigated were synthetic elastomer liquid, two-part epoxy, and aerosol adhesive. **Table 2** summarizes the adhesive properties provided by manufacturers.

Experimental methods

While the data in Tables 1 and 2 are useful for selection of packing material and the general use of adhesives, they do not provide the information needed to evaluate their potential for use in haunch forms. Because of this, tests were developed to evaluate the performance of combinations of packing foam and adhesive in haunch forms for precast concrete bridge decks.

These tests investigated the ability of the foam and adhesive combination to resist lateral pressures from concrete or grout, elongation that may occur due to adjustment after the foam is glued in place, and combinations of adjustment or elongation with subsequent lateral pressure. Other tests were used to investigate the response of the adhesive-to-foam bond strength to temperature and extension or compression of the system from panel geometry changes.

Test specimens

Each test used a standard specimen 3 × 1.5 × 10.5 in. (76 × 38 × 267 mm). **Figure 2** shows a typical specimen. The 3 in. height was chosen as a reasonable upper bound for a bridge haunch. A height-to-width ratio of 2:1 was chosen because it was a typical aspect ratio. The specimen

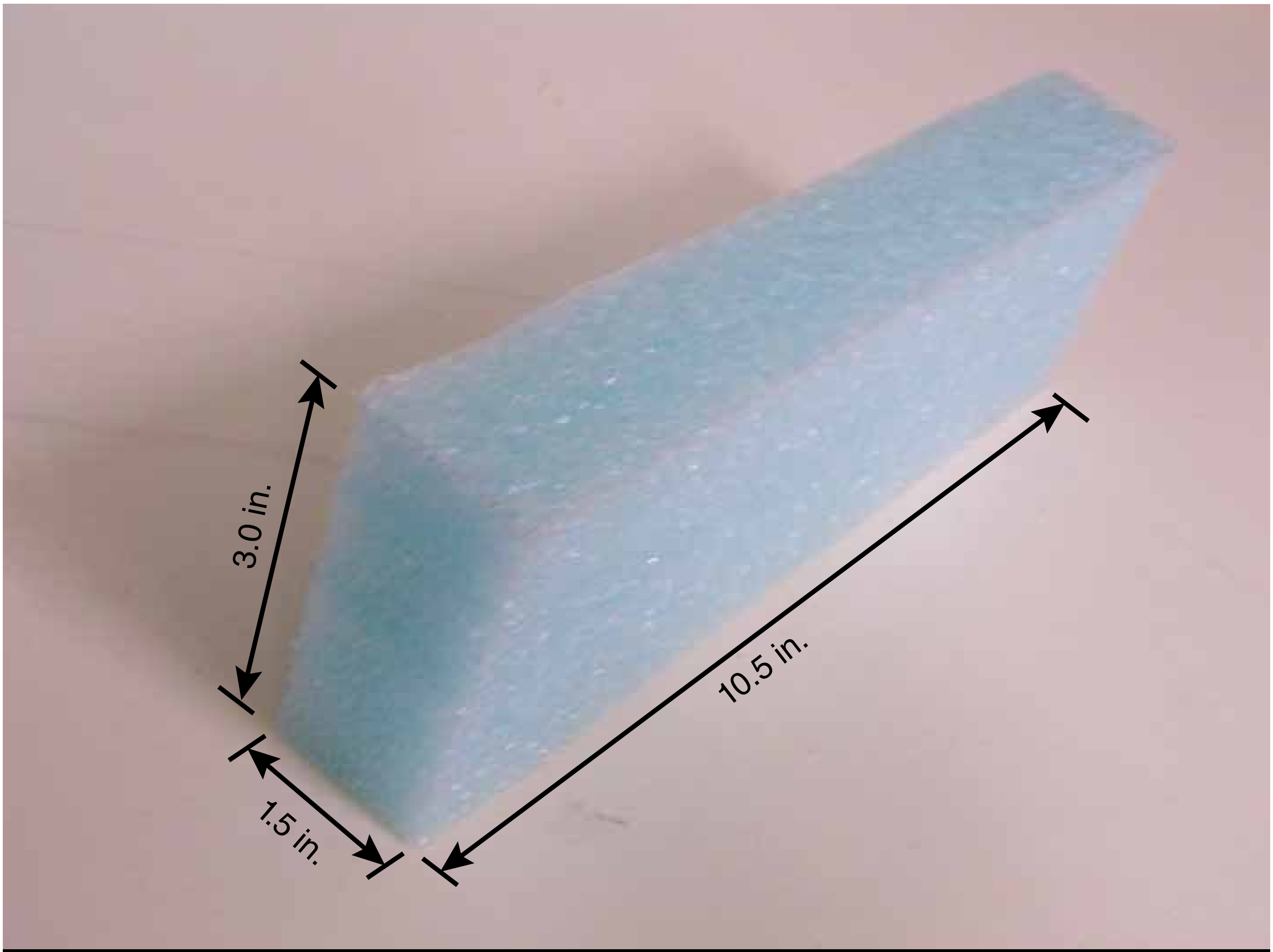

Figure 2. Dimensions of foam specimen used for testing. Note: 1 in. = 25.4 mm.

length of 10.5 in. fit the available testing equipment and was long enough to minimize edge-related behavior.

The test specimens were prepared according to the following procedure:

1. The foam was cut into 3 × 1.5 × 10.5 in. (76 × 38 × 267 mm) planks with a table saw.

2. Concrete blocks with dimensions 3 × 3 × 18 in. (76 × 76 × 460 mm) were made of 5000 psi (35 MPa) concrete with 1 in. (25 mm) nominal size aggregate.

3. A wooden jig was used to support the specimen to keep the foam plank vertical.

4. A concrete beam was placed in the jig and 10 g (0.35 oz) of adhesive was applied to thoroughly cover the interface between the concrete block and the foam surface. This was done to simulate the top surface of the precast concrete beam.

5. A foam plank was placed on the adhesive-covered surface.

6. Ten grams (0.35 oz) of adhesive was applied to the top surface of the foam in the same manner.

7. The formed surface of the concrete beam was placed on the foam to mimic the formed surface of the precast concrete panel.

8. This setup was then allowed to set under gravity load while supported in the jig for 24 hours.

While preparing the test specimen, it was important to ensure that the surface used on the concrete blocks was similar to the surface used in the actual structure. For this reason, the foam was glued to a troweled concrete surface to simulate the top surface of the precast concrete beam and to a formed surface to represent the bottom of the precast concrete panel.

Test methods

Three tests were conducted to investigate different combinations of foam and adhesive. These tests specifically investigated the ability of the foam and adhesive combinations to provide sufficient lateral pressure resistance, elon-

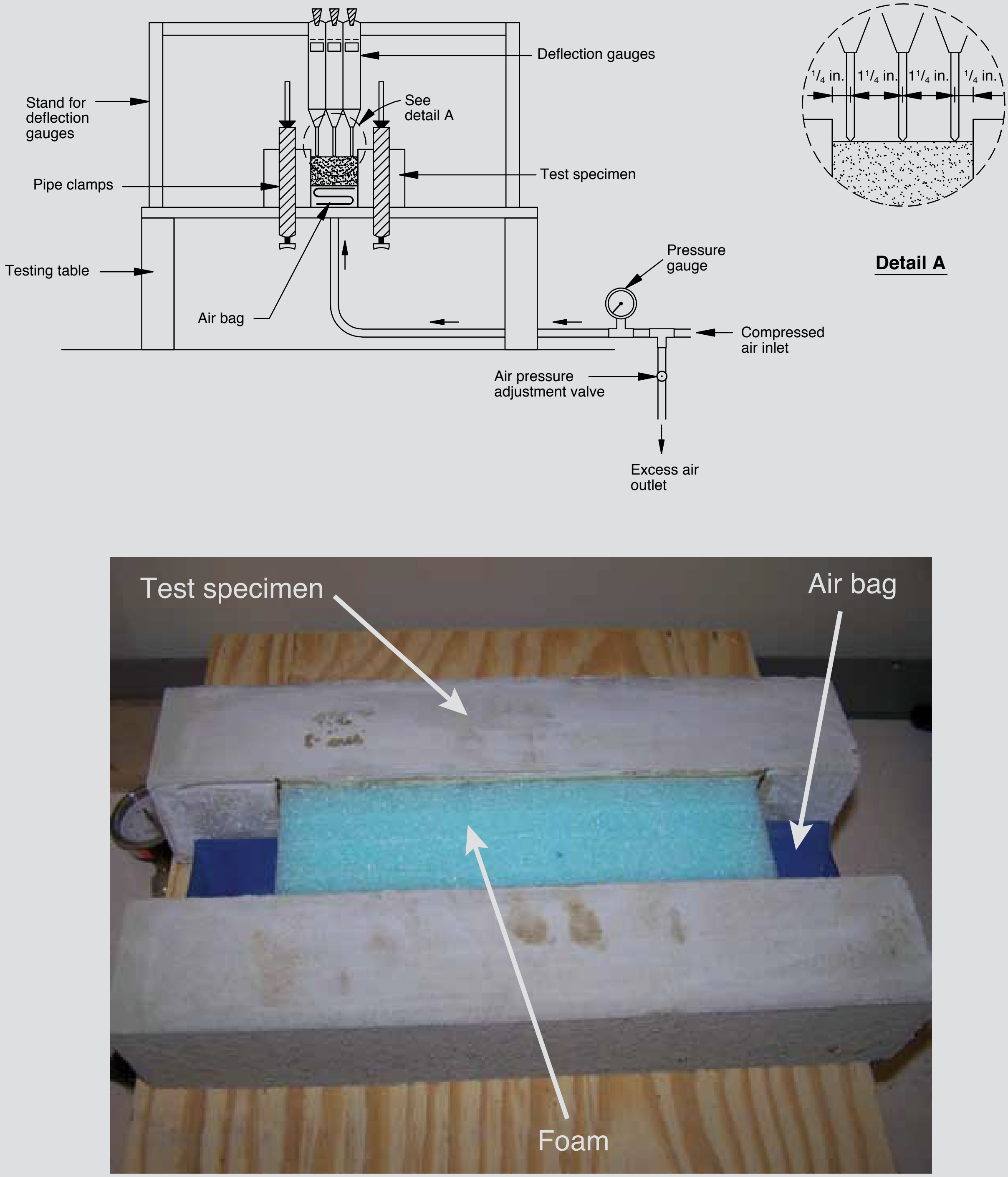

Figure 3. Experimental setup for lateral pressure test. Note: 1 in. = 25.4 mm.

gation, and memory. The lateral pressure tests were further modified to investigate combinations of elongation and lateral pressure as well as investigations with no adhesive or the effects of curing temperature on strength.

Lateral pressure test This test is designed to investigate the ability of the combined foam and adhesive to resist the fluid pressure of grout or concrete used to fill the haunch. This was achieved by examining the capacity of a foam strip glued on its top and bottom to a concrete block with one of the previously mentioned adhesives.

Pressure was applied to the foam using an air bag monitored with a pressure gauge and a regulator valve. The specimens were supported on their sides on a wooden table over an air bag while the concrete blocks were fixed

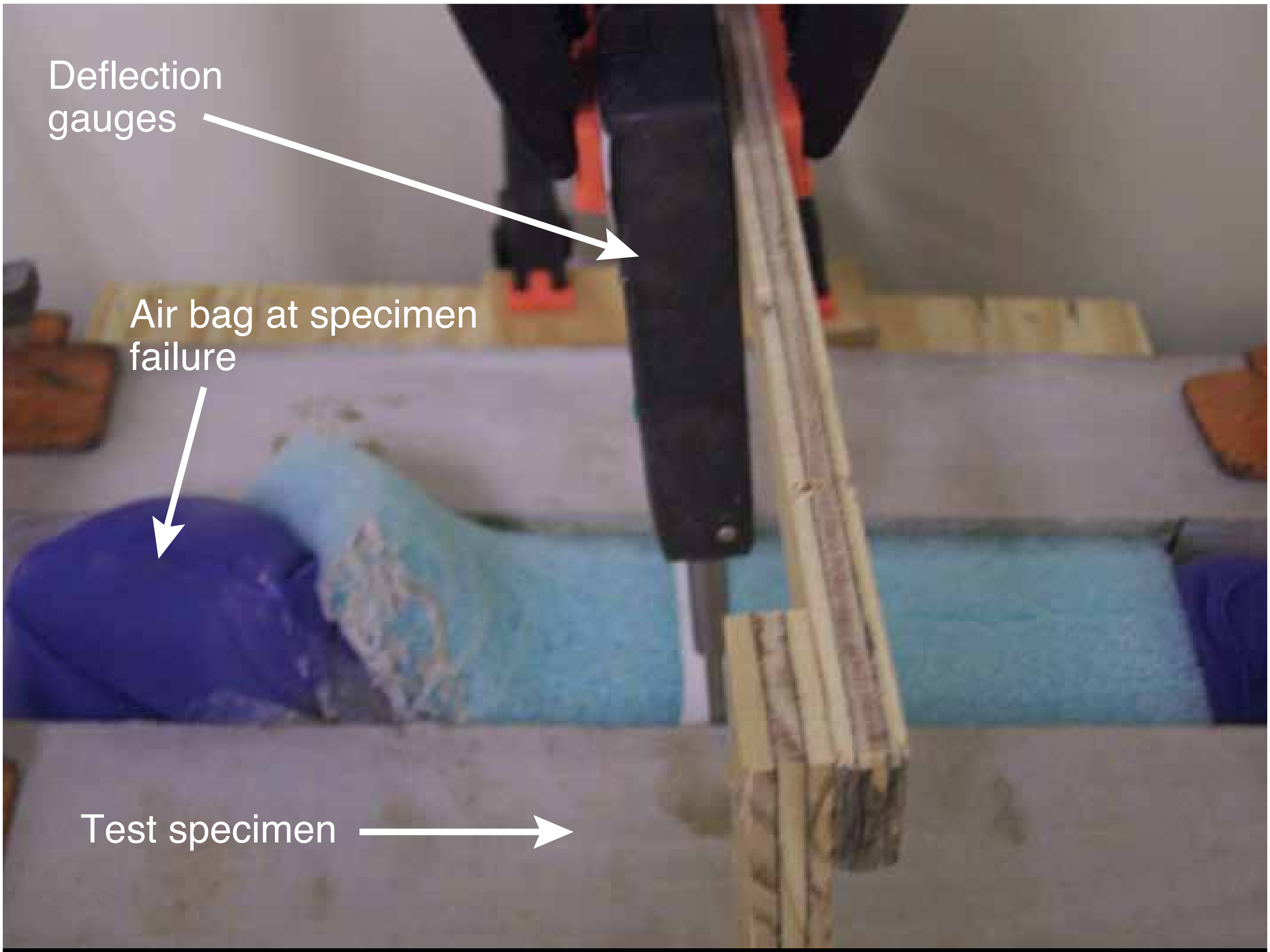

Figure 4. Lateral pressure test specimen at failure.

to the table using clamps. **Figure 3** shows the test setup. To ensure that the air bag applied pressure uniformly, the specimen was placed over the central region of the air bag (Fig. 3). Deflection gauges measured the deflection 0.25 in. (6 mm) from the edge and at the center of the specimen (1.5 in. [38 mm] from the edge).

This test was conducted after either 1 or 2 days of adhesive curing. These time periods were chosen to investigate the worst-case scenarios of wait times required before precast concrete panel adjustments could be made. Deflections of the foam specimens were measured at regular intervals starting at 1.5 psi (10 kPa) in increments of 1 psi (7 kPa) up to a maximum of 6.5 psi (45 kPa). At each increment the loading was held constant for 1 minute to allow the deflection of the system to stabilize. The value of 6.5 psi was chosen because it was the capacity of the air bag equipment used in the testing and it was also a reasonable upper bound on the pressure exerted by fresh concrete or grout. This would roughly correspond to a 6.5 ft (2.0 m) head of concrete or a 7.8 ft (2.4 m) head of grout.

Figure 4 shows an example of a failed specimen. Each result represents the mean of three individual tests. For each individual test, the lateral pressure at failure and specimen deflections at the different load steps were recorded.

Elongation and resistance to lateral pressure The lateral pressure test was modified to investigate the ability of the foam and adhesive combination to resist lateral pressure after elongation. This was done to simulate upward adjustment followed by lateral pressure after the adhesive had gained strength. The combination of tension on the adhesive with a subsequent shear from the horizontal pressure was thought to possibly be critical. This was evaluated by comparing the lateral pressure capacity of the foam and adhesive after elongation by 0.25 in. (6 mm). A value of 0.25 in. was chosen for the elongation because none of the foam and adhesive combinations failed at this elongation.

After a specimen was placed in the testing setup (**Fig. 5**), small screw jacks were used to elongate the specimen by 0.25 in. The specimen was then clamped to the testing table and a lateral pressure applied. The deflection at different lateral pressures was completed in a similar manner to the lateral pressure test.

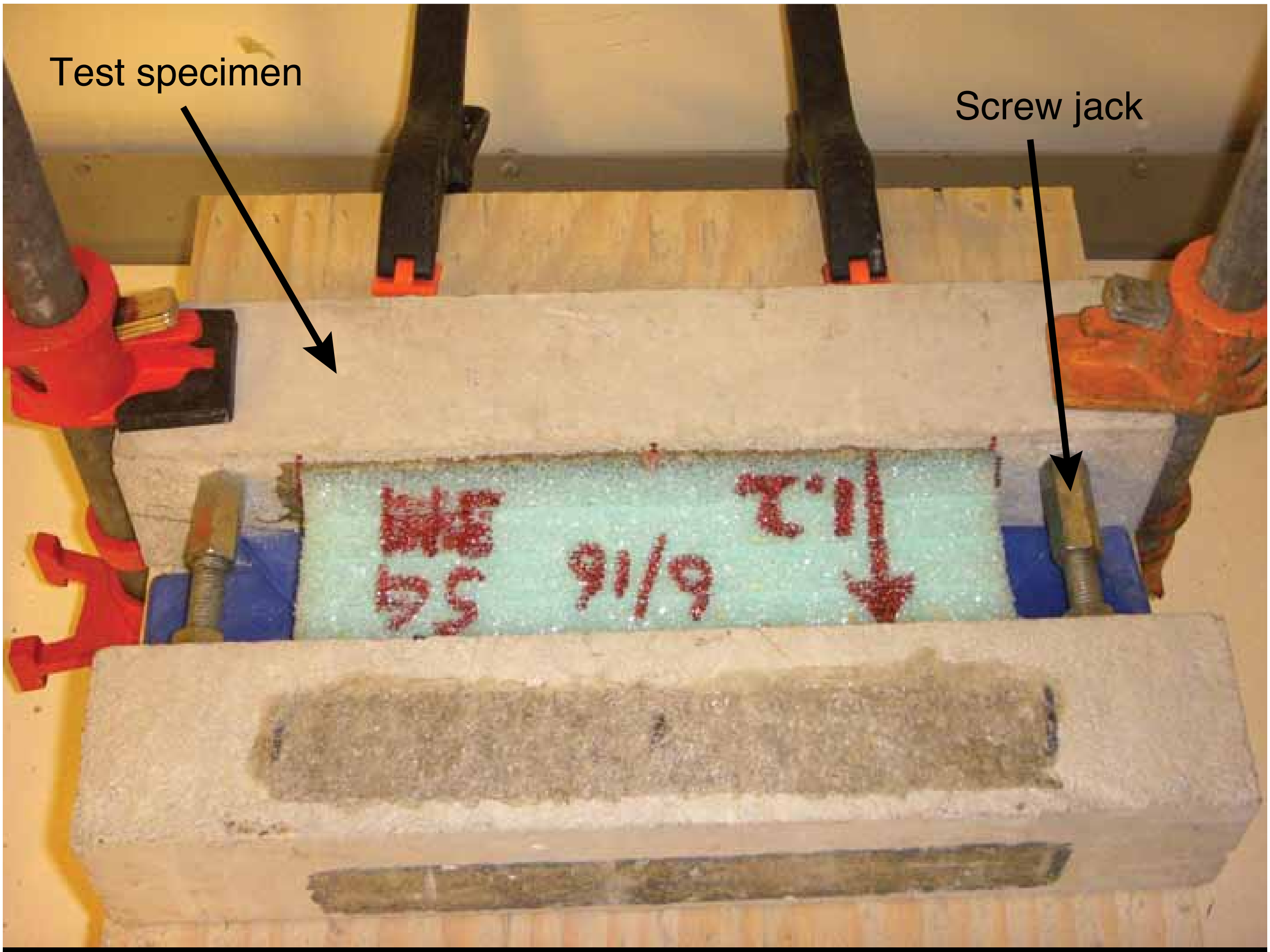

Figure 5. Elongating and lateral pressure test specimen using screw jacks for elongation and resistance to subsequent lateral pressure.

Lateral pressure test without adhesive This test investigates the use of the friction created by the dead weight of the panel to hold the foam in place. This could improve the constructability of a forming system because adhesive would not be needed. Foam specimens were compressed by 0.25 in. (6 mm), 0.5 in. (13 mm), 0.75 in. (18 mm), and 1 in. (25 mm) and then subjected to lateral pressure.

Elongation test This test focused on the tensile strain capacity of the combined foam and adhesive. It simulates the elongation of the foam after being glued. This ability to allow for adjustment is crucial to the constructability of the forming system.

To simulate this, a specimen was pulled in tension after different curing durations. The specimen was loaded at a rate of 10 lb/minute (44 N/minute). This rate was used because it was easy to observe the load on the specimen and it was a reasonable approximation of field loadings. The specimens were prepared as described previously and then clamped to steel plates fixed to the load heads of the machine. A level was used to minimize any eccentricities. During the testing, two deflection gauges were used to monitor the deflection of the specimen. **Figure 6** shows the test assembly. Care was taken to ensure that the initial height of the foam was 3 in. (76 mm) and had not been inadvertently changed while securing the specimen.

The specimen was loaded until the foam-to-adhesive bond developed a tear wide enough for grout to pass through (about $^{1}/_{16}$ in. [2 mm]). **Figure 7** shows an example of a failure. Observation was facilitated by a light behind the specimen to highlight the tearing. The load was then stopped and the deflection readings on the gauges were recorded. Elongation was measured at failure up to 1 in. (25 mm) with 0.005 in. (0.001 mm) precision. If the specimen had not failed at 1 in. (25 mm) elongation, the test was stopped and an elongation of 1 in. was reported. The value of 1 in. was chosen because it was the range of the deflection gauge used in testing, and it is also a reasonable upper bound to the amount of elongation that one might see during adjustment of the height of a precast concrete overhang panel.

Memory test A test was conducted to evaluate the ability of foam to return to its original height after being compressed by 50% of its original height. Its ability to return to its original geometry after loading is the elasticity, often

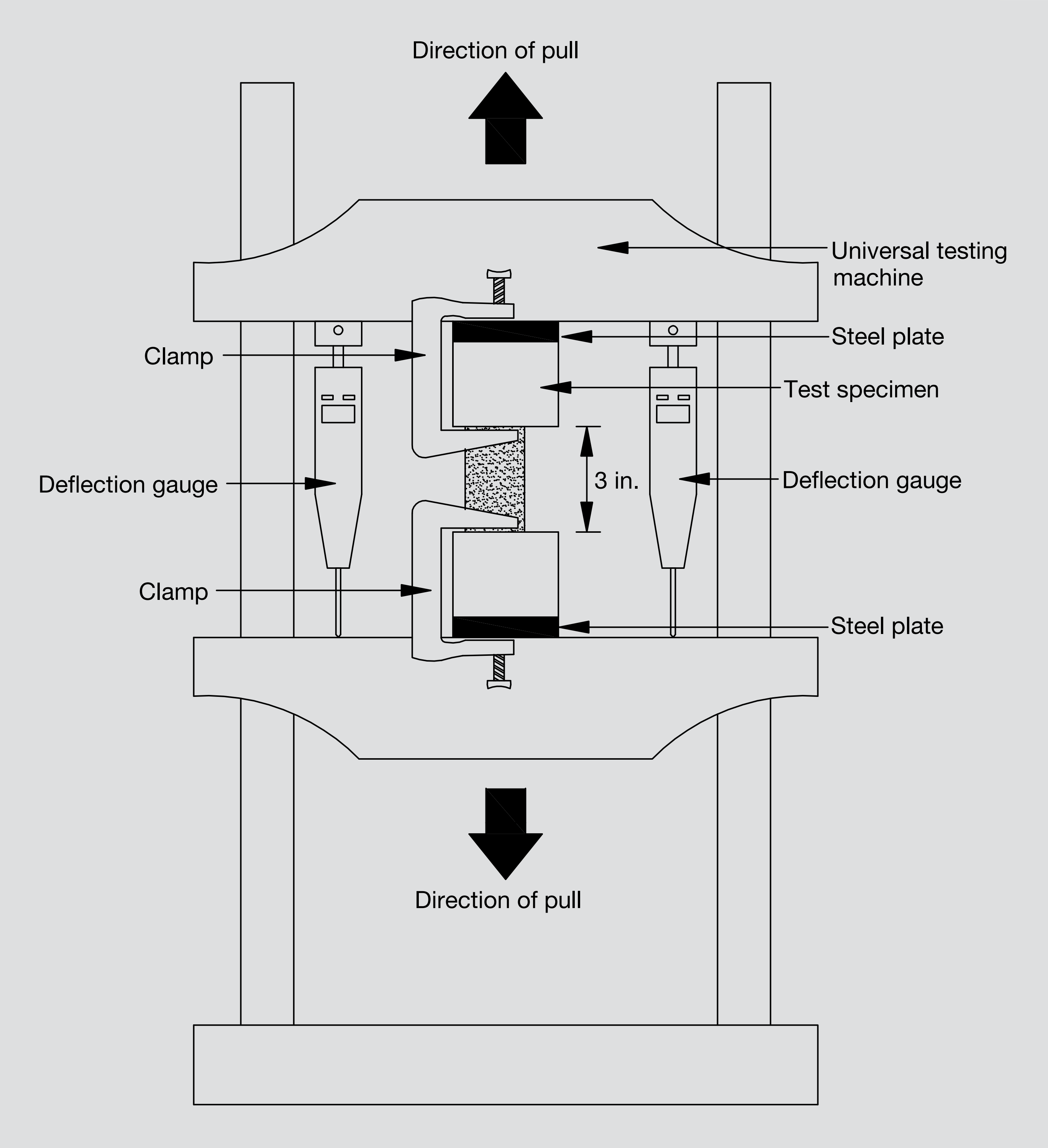

Figure 6. Experimental setup for the tension test. Note: 1 in. = 25.4 mm.

referred to as the memory of the foam. This test estimated the change in height expected from the foam if a precast concrete panel was initially placed directly on the foam and then raised with grade bolts. If the system is raised after the adhesive has gained strength, the adhesive and foam could be placed in tension. If this geometry change occurs before the adhesive has gained strength, the foam will need to elongate to remain in contact with the panel above. This information can be useful to evaluate adjustment restrictions on raising panels during construction.

For this testing, an unglued foam specimen was compressed between two concrete blocks. Each specimen was compressed to 1.5 in. (38 mm), or 50% of its original height, using pipe clamps. Two sets of three individual specimens were investigated; one set was left for 1 day and the other for 7 days. The height of each specimen was measured immediately after release, then after 10 min-

Figure 7. Failed specimen during tension test.

utes, 1 hour, and 4 hours. The final reading was taken at 24 hours.

Results

Different combinations of packing foams and adhesives were evaluated with the tests described previously to investigate the ability to resist lateral pressure, elongation, elongation with lateral pressure, and some slight modifications of these tests to simulate the performance of the haunch at different phases during construction.

Table 3 summarizes the results; the mean and standard deviation are presented for three replicate tests. The maximum pressure investigated in the lateral pressure and elongation and lateral pressure tests was 6.5 psi (45 kPa). If a specimen exceeded this capacity, the value was reported as 6.5 psi. A standard deviation of zero means that all specimens had identical results. The foam-adhesive combination in the different tests was investigated with a cure time of either 1 or 2 days to evaluate how the strength of the adhesive changed with time.

Not all combinations of foam and adhesive were investigated for this testing. From preliminary testing, the synthetic elastomer liquid appeared to be the most practical because of its ease of placement and economy, so it was used to evaluate the performance of each foam. To compare the adhesives, foam 2 was investigated with all three adhesives.

Figure 8 shows the capacity of the foam to resist lateral pressure when there is no adhesive at different levels of compression. Each result is the mean of three tests result. No standard deviation is shown on the graph because the lateral pressure at failure did not vary. The maximum pressure investigated in this test was 6.5 psi (45 kPa).

Discussion

The performance for the foam and adhesive combinations are discussed in terms of the results from each test.

Lateral pressure test

The lateral pressure test investigated the ability of a foam-adhesive combination to resist lateral pressure from the fluid grout or concrete used to make a connection between the precast concrete members. The results for this test

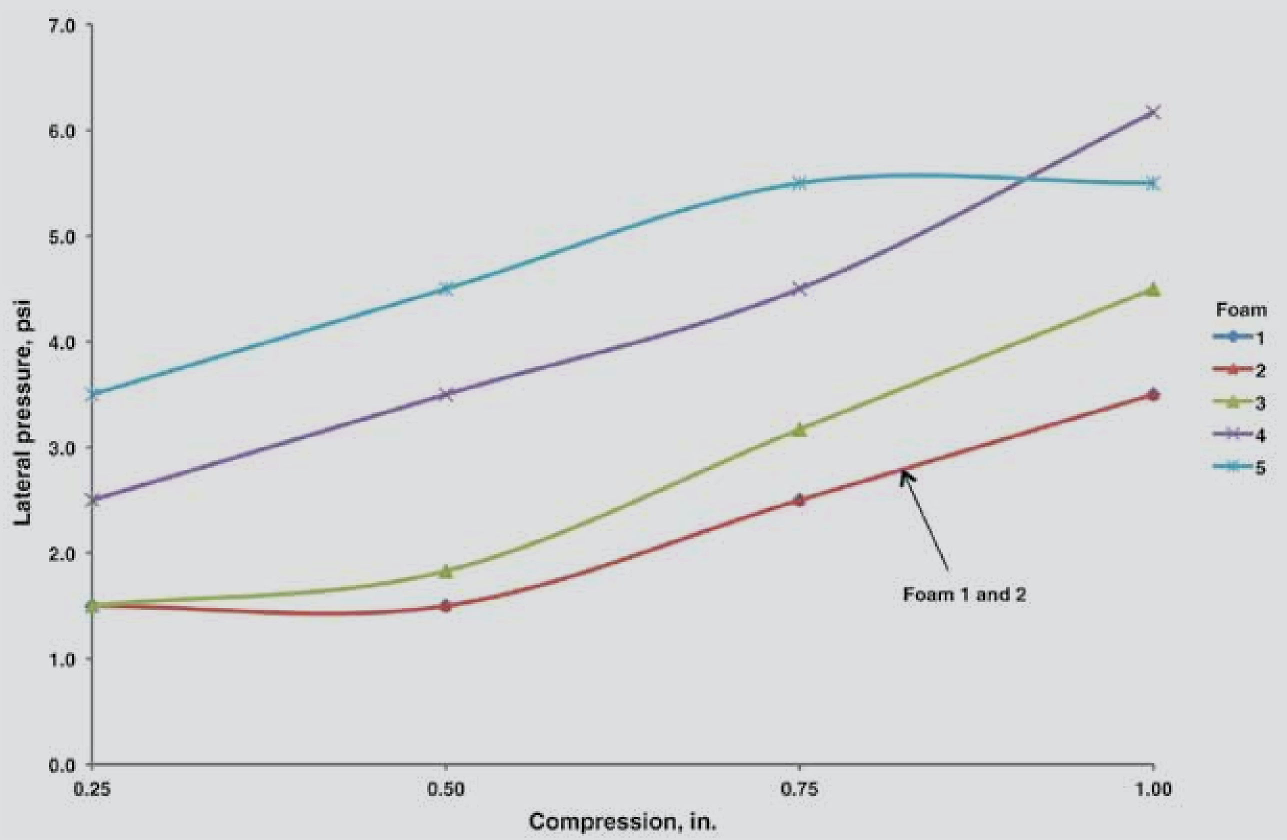

Figure 8. Lateral pressure test results with no adhesive and with a given amount of compression. Note: 1 in. = 25.4 mm and 1 psi = 6.895 kPa.

should be considered conservative because the failure of the foam-adhesive combination always occurred at the ends of the foam members or where the adhesive was terminated (Fig. 4). The area where the adhesive was terminated saw additional bending stresses because it was at the end of the member and the air bag was not confined outside of the length of the foam. Although this test setup does not exactly mimic the loading condition that will be used for a haunch form, it should provide a conservative estimate of the strength.

After 2 days of curing, foam 2 and the synthetic elastomer liquid can resist greater than 6.5 psi (45 kPa), foam 2 and the two-part epoxy can resist 4.5 psi (31 kPa), and foam 2 and the aerosol adhesive can resist 4.8 psi (33 kPa) lateral pressure. It is desirable to provide as much lateral pressure resistance as possible to resist a form failure, so the synthetic elastomer liquid has the best performance of the three adhesives. The synthetic elastomer liquid also has the lowest price and was the easiest to apply of the adhesives investigated.

When the results for samples cured for 1 day and 2 days are compared, the synthetic elastomer liquid and aerosol adhesive gained some strength on the second day, while the two-part epoxy had the same strength on the second day. It would be ideal to cure the haunch for 2 days or find a way to accelerate the strength gain before the grout or concrete is placed. However, the synthetic elastomer liquid with foam 2 could still be used after 1 day because it provides 4.8 psi (33 kPa) of lateral pressure resistance. This is equivalent to a head of 4.8 ft (1.47 m) of concrete or 5.8 ft (1.77 m) of grout (assuming a unit weight of concrete of 145 lb/ft^3 [2310 kg/m^3] and of grout of 120 lb/ft^3 [1920 kg/m^3]). With conventional gravity feed methods of placement, these pressures would not be expected to be exceeded.

Elongation and resistance to lateral pressure test

A modification to the lateral pressure test was made to study the behavior of the haunch system after elongation of the foam by $^1/_4$ in. (6 mm). An approximately 20% reduction in strength was measured for foam 2 and the synthetic elastomer liquid and foam 2 and the two-part epoxy when the results of this test were compared with the lateral pressure test. However, the strength of the rest of the foam and adhesive combinations was not significantly affected. This result suggests that the foam adhesive combinations could be raised by up to $^1/_4$ in. (6 mm) above the original

Table 3. Summary of test results for memory test, lateral pressure test with no adhesive, lateral pressure test, elongation and lateral pressure test, and elongation test

Foam	Memory test*				Lateral pressure test, no adhesive†		Adhesive	Cure time, days	Lateral pressure test‡				
	Day 1		Day 7						AAP, psi	σ, psi	Deflection, in.		
	AHG, %	σ, %	AHG, %	σ, %	AAP, psi	σ, psi					Top	Center	Bottom
1	75.0	0.1	61.1	0.0	2.5	0.0	A	1	5.5	0.0	0.102	0.340	0.089
								2	>6.5	0.0	0.139	0.439	0.139
2	75.0	0.0	59.8	0.1	2.5	0.0	A	1	4.8	0.6	0.085	0.342	0.092
								2	>6.5	0.0	0.108	0.401	0.113
3	93.1	0.0	59.0	0.0	3.2	0.6	A	1	6.1	0.6	0.089	0.322	0.100
								2	6.3	0.0	0.106	0.317	0.101
4	87.5	0.0	70.8	0.0	4.5	0.0	A	1	>6.5	0.0	0.059	0.243	0.066
								2	n.d.	n.d.	n.d.	n.d.	n.d.
5	97.2	0.1	83.3	16.7	5.5	0.0	A	1	45.8	1.2	0.051	0.216	0.053
								2	>6.5	0.0	0.054	0.122	0.055
2	n/a	n/a	n/a	n/a	n/a	n/a	B	1	4.5	0.0	0.018	0.183	0.046
								2	4.5	0.0	0.019	0.181	0.050
2	n/a	n/a	n/a	n/a	n/a	n/a	C	1	3.8	1.2	0.038	0.182	0.063
								2	4.8	0.6	0.141	0.338	0.099

* The result of the memory test is the average height, % when the foam specimen is compressed to 50% of its height and then released after the different time periods listed. The measurements are taken after 24 hours.

† Results of lateral pressure test with no adhesive represent the air pressure at failure when compressed by 0.75 in.

‡ The maximum pressure investigated in lateral pressure test and elongation and lateral pressure test for any specimen was 6.5 psi. If all specimens exceeded this capacity then the result was reported as >6.5.

Note: AAP = average air pressure; AE = average elongation; AHG = average height gain; n/a = not applicable; n.d. = no data; σ = standard deviation.
1 in. = 25.4 mm; 1 psi = 6.895 kPa.

foam height after the adhesive has cured. This finding allows contractors some flexibility during construction of the bridge deck to ensure that the proper geometry is obtained.

Lateral pressure test: No adhesive

In this test, foam specimens were tested without adhesive to investigate the need for adhesive between foam and concrete. From the results (Fig. 8), it can be inferred that as the stiffness of the foam increases, its resistance to lateral pressure also increases. Because the deformation of the foam was held constant, greater stiffness would result in a larger normal force at the concrete-foam interface. This larger normal force in turn increases the friction between these members and hence the capacity to resist lateral pressure. Test results show that foams 1, 2, and 3 have a low resistance to lateral pressure in the absence of adhesive. However, foams 4 and 5 show lateral pressure resistance of 4.5 and 5.5 psi (31 and 38 kPa), respectively, at 0.75 in. (18 mm) compression.

These results suggest that it may be possible to use cross-link foam without an adhesive to resist the lateral pressures of grout or concrete. This would be one less step in the construction process and therefore a benefit. However, it may be difficult to ensure uniform loading of the foam by the panels in the field, especially if their geometry is adjusted by grade bolts. Also, it may be necessary to use some adhesive to maintain the panels in the correct location during construction. The use of adhesive would be necessary if the precast concrete panel is raised for geometry adjustments. These results provide assurance that some lateral pressure resistance would be expected if insufficient adhesive were used during construction.

Elongation test

This test result provides limitations for raising panels if the top of the foam is glued to the bottom of the panel to allow for two-way adjustments during construction. Minimum elongation of 0.30 in. (7.6 mm) was found to be acceptable for any combination of foam and adhesive (Table 3). Test results also show that as the stiffness of the foam increases the stresses on the adhesive increase with a constant elon-

Elongation and lateral pressure test					Elongation test	
AAP, psi	σ, psi	Deflection, in.			AE, in.	σ, in.
		Top	Center	Bottom		
5.6	1.2	0.129	0.335	0.134	0.908	0.130
>6.5	0.0	0.130	0.423	0.160	0.888	0.090
3.5	0.0	0.114	0.307	0.145	0.363	0.050
6.2	0.0	0.125	0.243	0.116	0.825	0.230
>6.5	0.0	0.097	0.295	0.089	0.364	0.020
>6.5	0.0	0.095	0.336	0.108	0.696	0.280
>6.5	0.0	0.057	0.177	0.060	0.754	0.220
n.d.	n.d.	n.d.	n.d.	n.d.	0.661	0.300
6.2	0.6	0.043	0.241	0.087	0.310	0.030
6.2	0.6	0.078	0.131	0.069	0.396	0.040
3.5	1.0	0.013	0.092	0.013	0.324	0.150
n.d.	n.d.	n.d.	n.d.	n.d.	0.327	0.050
n.d.	n.d.	n.d.	n.d.	n.d.	0.318	0.180
n.d.	n.d.	n.d.	n.d.	n.d.	0.309	0.080

gation. This leads to a decrease in the ability of the system to deform before failure. The combination of foam 1 and the synthetic elastomer liquid shows superior performance, with elongation up to about 0.90 in. (23 mm), while foam 5 was only able to resist 0.30 in. of elongation. This ability of foam 1 and the synthetic elastomer liquid to elongate would provide greater flexibility during construction and would therefore be preferred over other foam and adhesive combinations.

Memory test

This test evaluated the foam's ability to regain height after being compressed to half of the original height and then released. Although this test has been completed under a specific loading, this gives an indication of the foam's memory. Foams 1 and 2 regained about 75% of their original height after 24 hours; foams 3, 4, and 5 regained 93%, 87%, and 97%, respectively, of their original height after 24 hours (Table 3). For the tests with sustained loading for 7 days, similar trends were observed with less memory for each of the foams.

As the stiffness of foam increases, the capability of the foam to regain height also increases. This suggests that a precast concrete bridge deck system should be adjusted within 1 day of panel installation if possible. If adjustments are made after 7 days, the adhesive and foam combination would have less ability to elongate than if the adjustments were made after 1 day.

Synthesis of results

The memory data suggest that if a precast concrete bridge deck panel is raised beyond 0.4 in. (10 mm) using foam 1, 2, or 3 or 1.41 in. (36 mm) using foam 4 or 5 after initially being compressed to 50% of its original height (3 in. [76 mm] for this testing), adhesive needs to be used on the top and bottom of the foam so that there is no gap between the foam haunch form and the precast concrete panel.

From the lateral pressure tests with no adhesive, foams 4 and 5 showed the ability to carry significant lateral pressure. It may be possible to use these foams as a haunch form without applying adhesive. This would have to be investigated based on the weight of the precast concrete panels used, modulus of the foam, size of the foams, and the lateral pressure that may be applied. Based on the authors' experience, it may be difficult to compress these foams from the self-weight of the precast concrete panel and ensure uniform compression due to construction tolerances. This would require that the foam be cut to a height close to the final haunch height.

One important foam parameter is its ability to be compressed by the self-weight of the bridge deck system. While this parameter is not discussed directly, it can be inferred from the compressive stiffness information in Table 1. If a foam is stiff, then the self-weight of the precast concrete deck panel may not be able to cause the foam to deflect downward. Of the foams investigated, foam 1 had the lowest compressive stiffness and so would provide the most flexibility during construction. While buckling of the foam could prove problematic, it was never seen with the 2:1 aspect ratio used for this testing.

In all of the testing, the combination of foam 1 and the synthetic elastomer liquid showed good performance, including the highest lateral pressure and elongation capacity. Hence it is recommended that this combination be used for an adjustable haunch system.

Another parameter that was not considered in the data presented but that is also important is the aesthetics of the foam that may be used on the exterior of the bridge in a visible location. Polyethylene foam is available in distinctive colors based on density. The typical color for foam 1 is gray, which is similar to concrete, so it would not cause aesthetic problems. This foam and adhesive combination was successfully used to construct a precast concrete bridge deck system in Cool, Tex., during the summer of 2009. Images from the construction can be seen at www.precastoverhang.com, and details can be found in other publications.[7] However, adhesive was only placed between the bottom of the foam and the concrete beam. The foam height was adjusted so that it was 0.5 in. (13 mm) higher than what was needed. This meant that the foams were always in compression during construction. Although this system was not directly investigated in this paper, it performed well in the project.

Conclusion

Combinations of packing foam and adhesive were investigated to be used as a haunch forming system for an adjustable precast concrete bridge deck. This forming system allows the precast concrete deck panel to be adjusted during construction without forming work to be completed below the bridge for installation or removal. This increases the safety, constructability, and economy of these systems.

A number of combinations proved to be possibly successful haunch forming systems. It is recommended that the 1 lb/ft^3 polyethelene foam is used in combination with the synthetic elastomer liquid adhesive. These materials were used in the construction of a precast concrete bridge deck system.[7] This system was able to resist a lateral pressure over 6.5 psi (45 kPa), or approximately 6.5 ft (2.0 m) of concrete, and an elongation of 0.9 in. (23 mm) before failing. In addition, the foam is a gray color similar to concrete.

While this testing was completed with specific sizes of haunch forms, other heights and configurations could be evaluated based on the data presented. Furthermore, while the focus of this paper was on haunch forming systems, the same concepts could be used in any system using field-adjusted precast concrete elements, such as parking garages or buildings.

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Abstract

Precast concrete bridge decks have not been widely adopted for a number of reasons. One significant reason is that these systems require manual forming to complete the construction of the area between the girders and the deck or haunch after field adjustment. An adjustable forming system is presented that uses commonly available packing foams and adhesives. Several novel test methods were developed to investigate the performance of these systems from different precast concrete bridge deck construction processes. A recommendation is made for materials to be used, and a typical construction sequence is presented.

Keywords

Bridge, deck, foam, formwork, haunch, polyethylene.

Review policy

This paper was reviewed in accordance with the Precast/Prestressed Concrete Institute's peer-review process.

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