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HPC ACCOMPLISHMENTS UNDER TEA-21—WHAT'S NEXT?

Louis N. Triandafilou, Federal Highway Administration

Many articles in previous issues of *HPC Bridge Views* have described projects that have been designed and constructed as a result of legislation responsible for implementing longer-lasting, cost-effective bridges nationwide. Industry and FHWA have also outlined their strategic plans and visions for concrete bridges through the use of high performance concrete (HPC).* We will now pull together these various elements that have been accomplished directly and indirectly as a result of the 1998 Transportation Equity Act for the 21st Century (TEA-21).

TEA-21's Innovative Bridge Research and Construction (IBRC) Program has been highly successful in supporting FHWA's strategic goals for enhancing safety, increasing productivity, and promoting mobility (congestion mitigation). Currently, IBRC is in the last year of a six-year program. IBRC funds have been used by almost all State Departments of Transportation (DOTs) and several Federal and local agencies to extend the service life of their structures cost-effectively by incorporating high performance materials. More than half the States have funded HPC projects in a myriad of applications.

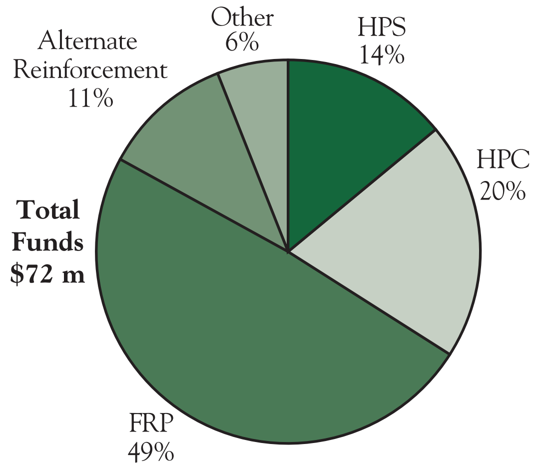

Fig. 2 Allocation of IBRC funds by material

Figures 1 and 2 depict the broader view of HPC accomplishments for fiscal years 1998-2002 under TEA-21. Forty-one HPC-related projects have been funded during the first five years of the IBRC program. Of the $72 million in project allocations, about one-fifth has gone to projects incorporating HPC bridge components or elements. Nineteen HPC projects have been submitted for review and approval under the last year of the program (FY 2003).

By far, cast-in-place bridge deck construction has been the most common application of high performance concrete with 40 bridges constructed under the IBRC program. In a few instances, HPC full-depth precast, prestressed concrete deck panels have been used. An early leader in HPC technology, Virginia, is planning to construct an HPC lightweight concrete bridge deck and one with fibers. State DOTs are seeking ways to extend the service life of existing sound concrete bridge decks by using HPC

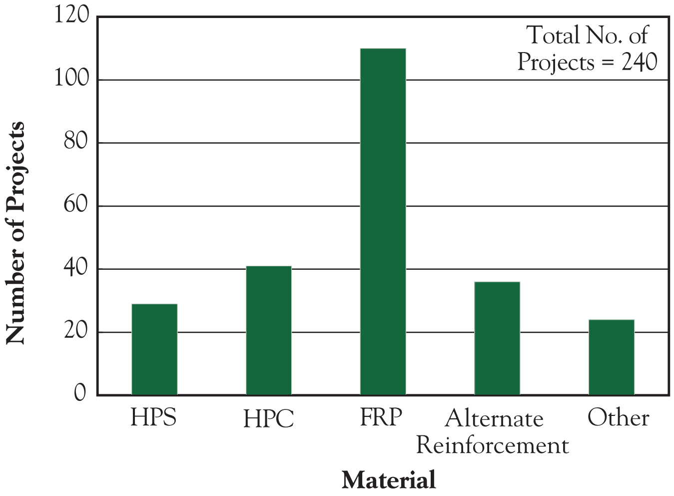

Fig. 1 Number of projects by material for the IBRC program

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*See HPC Bridge Views, Issue Nos. 17, 20, and 25.

(continued from pg. 1)

overlays in seven bridges. In addition, HPC has been used in the parapets or railings of three bridges.

Prestressed concrete girder superstructures are the next most common application of HPC with 20 bridges built under the IBRC program. HPC substructures and foundations, including piling, pile bents, solid piers, and precast abutments, have been funded on ten additional bridges. In at least two instances, HPC has been used in all components and elements of a bridge.

As a result of the IBRC program and routine Federal-aid funding, some States are using HPC on a regular basis. Virginia has over 100 HPC projects constructed, under construction, or in the design phase. Ohio and New York have incorporated HPC specifications for routine bridge deck use for several years, and as we learned in *HPC Bridge Views*, Issue No. 24, Ohio has implemented a warranty specification for contractor workmanship.

In conjunction with the success of TEA-21's IBRC program, FHWA and the concrete industry have forged strategic plans that are closely aligned regarding HPC implementation. As reported in *HPC Bridge Views*, Issue No. 20, this plan focuses on the public's transportation expectations for the present and future with the following goals: reducing congestion and improving safety; training the workforce; reducing life-cycle costs; and ensuring that bridges meet expectations. In the last issue of *HPC Bridge Views*, FHWA's proposed Structures Research and Technology Program vision is to "get out in front of the bridge deterioration curve and stay there." The ***Bridge of the Future*** will be one focus area to accomplish this vision, with a whole host of performance objectives. HPC fits very neatly into objectives related to minimal maintenance, constructibility and reduced construction time, lower life-cycle costs, and the cost-effective systems approach.

The FHWA HPC Technology Delivery Team (TDT), described in Issue No. 19, is another indirect offshoot of TEA-21 legislation. This partnership of several agencies, industry, and academia is still in its infancy, but is already working towards goals that align with the strategic plans of the National Concrete Bridge Council and the FHWA. One specific product of the group's efforts is the rollout of an HPC knowledge-sharing website which now allows users to subscribe to an e-mail notification system where they receive a summary of postings for any one of eight focus areas. The site has experienced a high usage rate in its first few months of existence. If you have not already visited the site, please go to http://knowledge.fhwa.dot.gov/cops/hpcx.nsf/home.

Finally, post-TEA-21 legislation has brought HPC to the forefront. Under 1999 and 2000 DOT Appropriations Act provisions, Congress made funds available for research and development on the use of silica fume in concrete. Additional usage will decrease waste materials and increase the quality and durability of concrete structures and pavements. The silica fume program will highlight development of the following partial list of products: web site, guide specification, service life prediction model, user manual, and other technology transfer materials.

In summary, there have been many HPC accomplishments that have resulted from TEA-21 and subsequent legislation. State DOTs and local agencies have gained a tremendous amount of experience with implementing HPC, largely through IBRC program funding. We look to the continuation of these efforts with the implementation of the strategic plans, heightened HPC TDT activities, and the silica fume program. The broadened and redirected research and construction program being proposed for TEA-21 reauthorization will play a key role in expanding HPC technology and making HPC the concrete material of choice for many bridge applications.

The author would like to thank John M. Hooks for the information on the IBRC program, Steven B. Chase for the strategic plan information, and Jon I. Mullarky for the status of the silica fume program.

Further Information

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HPC ON THE OHIO TURNPIKE

William R. Fleischman, Ohio Turnpike Commission

HPC, epoxy-coated reinforcement, and a silane sealer were used to provide a durable deck.

In conjunction with the Third Lane Widening program, the Ohio Turnpike Commission is reconstructing the twin, high-level bridges over the Cuyahoga River Valley in Summit County, near Akron, Ohio. The new 18-span structures are each 2,660 ft (811 m) long and approximately 175 ft (53 m) above the Cuyahoga River Valley. The Cuyahoga River Bridges are the longest and highest structures on the Ohio Turnpike's 241-mile (388-km) long system. The project has a total construction cost of $52 million.

The new eastbound structure, constructed on a new alignment, was completed and opened to traffic in October 2001. The old eastbound structure was subse-

(continued from pg. 2)

Concrete Mixes		
Material or Property	**Girders**	**Deck Barriers Diaphragms**
Mix Proportions		
Portland Cement, lb/yd^3	800	440
GGBFS, lb/yd^3	—	190
Silica Fume, lb/yd^3	—	30
Fine Aggregate, lb/yd^3	1250	1370
Coarse Aggregate, lb/yd^3	1535(1)	1504(2)
Water, lb/yd^3	264	264
HRWR	Varies	Varies
w/cm ratio	0.33	0.40
Measured Properties		
Air content, %	6.2	6.2
Compressive Strength, psi	10,440	7000

(1) 615 lb of No. 8 stone and 920 lb of No. 57 stone
(2) No. 8 stone

quently demolished. The new westbound structure is currently under construction. All of the substructure units are in place and girder erection is almost complete. When the new westbound structure is complete, the old westbound structure will be demolished.

An Ohio Department of Transportation (ODOT) Class C mix with a required compressive strength of 4000 psi (28 MPa) was selected for use on the substructure units.

Girders

The 18-span superstructure of each bridge consists of three units. Unit No. 1, with a length of 357 ft (109 m), consists of three spans of 72-in. (1.83-m) deep precast, prestressed concrete girders. Six girders spaced at 11-ft 0-in. (3.35-m) centers are used in each span. Unit No. 2 consists of two spans of 150 ft (45.7 m) and three spans of 200 ft (61.0 m) for a total length of 900 ft (274 m). Seven precast, prestressed, post-tensioned spliced girders 102 in. (2.59 m) deep spaced at 9-ft 2-in. (2.79-m) centers are used in each span. Unit No. 3, with a length of 1399 ft (426 m), consists of ten spans of 84-in. (2.13-m) deep precast, prestressed girders. Six girders spaced at 11-ft 0-in. (3.35-m) centers are used in each span. Span lengths in Unit Nos. 1 and 3 range from 115 to 142 ft (35.1 to 43.3 m).

The girders have a modified AASHTO girder cross section obtained by increasing the depth and width. Individual casting lengths vary from 99 to 142 ft (30.2 to 43.3 m). The typical girder weighs approximately 170,000 pounds (77.1 Mg). The girders were transported to the site using dual 6-axle dollies.

The Unit 2 girders have two 4-in. (100-mm) diameter and eight 2-in. (50-mm) diameter ducts per girder. The 4-in. (100-mm) diameter ducts accommodate the longitudinal post-tensioning tendons and have a total length of 900 ft (274 m). Each longitudinal post-tensioning tendon consists of eighteen 0.6-in. (15.2-mm) diameter 7-wire strands. The 2-in. (50-mm) diameter ducts, with a length of 15 ft (4.57 m), are located in the beam end blocks to accommodate the 1.25-in. (32-mm) diameter post-tensioning bars at the field splices.

The specified concrete compressive strengths for the girders were 6500 psi (45 MPa) at transfer and 7500 psi (52 MPa) at 28 days. The 102-in. (2.59-m) deep girders were cast in sets of three in a casting bed 350 ft (107 m) long. Each prestressing strand had approximately 36 in. (914 mm) of elongation during tensioning. After the concrete was placed, the girders were steam cured for approximately 18 hours. In this short amount of time, the typical compressive strength reached 7500 psi (51.7 MPa).

The 84- and 72-in. (2.13- and 1.83-m) deep girders were cast in sets of two on a 350-ft (107-m) long automated hydraulic casting bed. After steam curing was completed, the formwork was removed in minutes using a hydraulic system mounted to the formwork shell. This automated formwork greatly enhanced production efficiency.

Deck

The bridge decks, barriers, and girder end diaphragms required 13,800 cu yd (10,600 cu m) of high performance concrete (HPC) with a specified 28-day compressive strength of 4500 psi (31.0 MPa). This HPC utilized ground granulated blast-furnace slag (GGBFS) and silica fume. The actual average strength was 7000 psi (48.2 MPa). Deck thickness is 9 in. (230 mm) in Units 1 and 3 and 8-1/2 in. (215 mm) in Unit 2. Stay-in-place metal forms were used in all deck placements.

The deck slab was designed utilizing ODOT bridge design standards. Several specialized materials were used to enhance the durability of the deck. The HPC provides a denser, less permeable concrete that reduces chloride penetration. The application of a silane concrete sealer further enhanced this resistance. All reinforcing steel in the deck is epoxy coated to provide additional protection against corrosion.

Deck placement sizes varied from 160 to 460 cu yd (122 to 352 cu m). End diaphragms were placed monolithically with the deck. Midspan sections of the deck were placed first and followed by the other sections. Deck placements for the new eastbound bridge deck occurred over a 17-day period. The deck concrete was cured for 7 days with wet burlap.

This project is scheduled for completion late in 2003 and is a key link in the program to add an additional lane in each direction on a 160-mile (258-km) long segment of the Ohio Turnpike.

Further Information

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HPC PRETENSIONED GIRDERS FOR THE METHOW RIVER BRIDGE

Stephen J. Seguirant, Concrete Technology Corporation

High strength concrete was used in the largest girders shipped in Washington State.

The Methow River Bridge, currently under construction in Okanogan County, Washington, is a replacement for a seven-span, cast-in-place concrete T-beam bridge that had become functionally obsolete. The new bridge consists of two 180.5-ft (55.0-m) long spans using precast, pretensioned, 176.5-ft (53.8-m) long Washington State Department of Transportation (WSDOT) W83G girders at 6.1-ft (1.85-m) centers.[1] The girders are 82.7 in. (2.10 m) deep and weigh 1.11 kips/ft (16.2 kN/m). The cast-in-place deck is 7.9 in. (200 mm) thick. Each span consists of seven girders for a roadway width of 43.3 ft (13.20 m). The bridge is being constructed in two stages. Stage 1, with three girders, is complete and open to traffic. The existing bridge has been demolished and Stage 2 construction is proceeding. The new bridge was subjected to many environmental restrictions, including a 10-month closure on construction in the river for fish protection.

The original design used a three-span bridge with WSDOT W74G, 73.5-in. (1.87-m) deep girders. However, this concept placed one of the piers in the middle of the main river channel, which is heavily used for recreation in the summer months. The conversion of the original concept to a two-span structure removed the pier from this channel, reduced the amount of work required in the river, and placed the pier in a location that is dry for much of the year.

Handling, Shipping, and Erection of Girders

To date, the Methow River Bridge girders are the largest to be constructed and transported in Washington State. Permanent pretensioning consists of sixty-eight, 0.6-in. (15.2-mm) diameter strands tensioned to 75 percent of the guaranteed ultimate tensile strength. The length and weight of the girders required special planning for handling and shipping.

Without the aid of temporary top strands, stability during stripping would require that the lifting devices be placed 12.3 ft (3.75 m) from the ends of the girders with a concrete strength at transfer of 8700 psi (60.0 MPa). With six temporary top strands, tensioned to the same stress level as the permanent strands, the lifting devices could be moved to 9.5 ft (2.90 m) from the ends, and the required concrete strength at transfer could be reduced to 8220 psi (56.7 MPa). The temporary top strands are placed 2 in. (50 mm) from the top of the girder, and are bonded for only 10 ft (3 m) at both ends of the girder. These strands are cut through pre-formed blockouts after the girders have been erected and stabilized.

In general, temporary top strands are not required for stability during handling, but in many cases, they are required for stability during shipping. Though temporary, these strands can affect the long-term camber, since much of the camber growth due to creep occurs early in the life of the member. The design of the Methow girders considered this effect. The thickness of the cast-in-place haunch at the girder ends was reduced by an estimated amount of 1.25 in. (30 mm) due to the reduction in camber.

For shipping, the contractor was given several options for support configurations and overhangs to fit the three different truck configurations used to haul the girders. Calculations indicated that a rotational stiffness of approximately 50,000 in.-kips/radian (5.65 MN-m/radian) was needed per truck to assure an adequate factor of safety against rollover. Based on previous measurements and the number of axles required to carry the weight of 197,000 lb (876 kN), the trucks were deemed adequate for the haul. All girders were safely delivered from Tacoma to the site; however, the journey along the 250-mile (400-km) long route took from 9 to 13 hours. The girders were erected in as little as 20 minutes each with a crane positioned at each end.

Concrete

The specified 28-day concrete compressive strength for the girders was 10,000 psi (69 MPa). The concrete mix proportions included 752 lb/cu yd (446 kg/cu m) of Type III cement and 50 lb/cu yd (35.6 kg/cu m) of silica fume, placed with a water-cementitious materials ratio of 0.27. State-of-the-art electrically heated forms allowed for optimum curing conditions. The actual concrete strengths at transfer ranged from 8300 to 12,500 psi (57 to 86 MPa) at one to three days. The actual 28-day strengths ranged from 10,600 to 15,200 psi (73 to 105 MPa).

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Further Information

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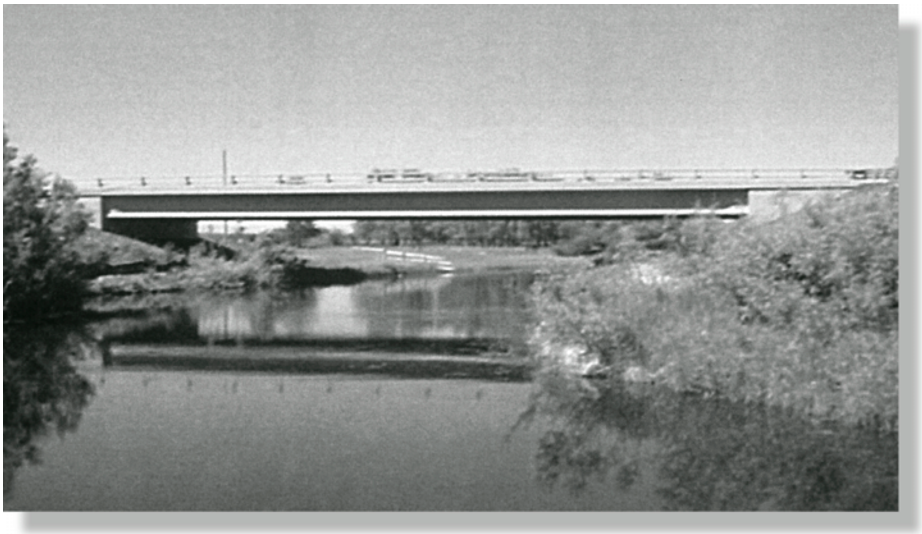
STURGEON RIVER BRIDGE: 100-YEAR SERVICE LIFE

Dale Serink, UMA Engineering Ltd.



Precast, prestressed concrete was selected for its shorter delivery and erection time.

Located near Edmonton, Alberta, the Sturgeon River bridge incorporates innovative features aimed at achieving a 100-year service life and meeting difficult geometric constraints. Integral abutment design, stainless steel-clad reinforcement, and high performance concrete were employed to achieve these objectives. The selected design consists of a single span 131-ft (40-m) long low profile precast, prestressed concrete girder bridge with high performance concrete in the deck and the girders.

Girder Design

The standard girder shape in Alberta at the time of construction was the bulb-tee girder available in three standard depths of 43.3, 55.1, and 66.9 in. (1100, 1400, and 1700 mm). For a 131-ft (40-m) single span bridge, a 66.9-in (1700-mm) deep girder is generally required. However, geometric constraints allowed only 55.1 in. (1400 mm) of girder depth at this site. In order to meet design requirements, a 131-ft (40-m) span high performance concrete and integral abutment design were employed.

Using high performance concrete in the girders allowed 0.6-in. (15.2-mm) diameter strands to be substituted for the standard 0.5-in. (12.7-mm) diameter strands, thereby, increasing the girder's capacity. Thirty-eight strands were required for each girder. A concrete strength at transfer of 6530 psi (45 MPa) and a design strength of 9430 psi (65 MPa) were specified to meet the requirements.

The girders were fabricated in Calgary and transported more than 185 miles (300 km) to the site by truck. The fabricator was able to achieve a one-day construction cycle for each girder and complete the fabrication ahead of schedule. There were initial concerns over transportation of the slender girders but no problems were encountered during fabrication or erection.

Bridge Deck Design

The most common service failure for bridge decks is corrosion of the top layer of steel reinforcement. Traditional methods of prolonging the onset of corrosion include reducing the permeability of the concrete, coating the steel with epoxy, or coating the top of the deck with a waterproof layer. All these methods have been effective but have not yet provided the desired increase in service life. To assure a 100-year service life, a more innovative deck design was required.

Rather than focusing on methods to protect the top layer of steel reinforcement, use of stainless steel-clad reinforcement was specified. Stainless steel differs from regular steel in that it is essentially neutral in an alkaline environment. The chromium content of the steel allows the formation of a self-healing chromium oxide film on the steel surface. Stainless steel-clad reinforcement combines a stainless steel outer layer with a carbon steel core to provide the benefits of stainless steel at a reasonable cost. This type of reinforcement is produced at a cost about double that of epoxy-coated reinforcement.

The concrete deck consisted of 7250 psi (50 MPa) compressive strength high performance concrete with a water-cementitious materials ratio of 0.30 and incorporating both silica fume and fly ash. This provided a high quality deck with greater resistance to carbonation and a minimum 100-year period for chloride ions to diffuse to the unprotected bottom layer of deck reinforcement.

The deck finishing proved to be more challenging than expected. Alberta Transportation's specifications require the use of magnesium floats to finish the concrete. For this sticky concrete mix, stainless steel floats seemed to reduce surface tearing and provided a superior finish. The deck was prepared for traffic with the application of 1/4-in. (6-mm) deep transverse grooves. Some tearing proved to be unavoidable during this operation, particularly in the last corner of the deck completed where the concrete had cured for a longer period before it was raked.

The new Sturgeon River bridge was completed in 16 weeks at a unit cost lower than the average unit cost for bridges of this category in Alberta. High performance concrete allowed the difficult constraints of the project to be met and will contribute to the long-term durability of the bridge. However, it is not the use of high-tech materials or the innovativeness of any single feature alone that provides an outstanding solution but the careful selection of technologies that complement each other to achieve the challenging goals of this project.

Further Information

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Question

What value of chloride permeability should I specify for a bridge deck?

Answer

Chloride permeability or, more appropriately, chloride penetrability is being widely specified to ensure longevity in our transportation structures. There has been considerable debate regarding appropriate applications and interpretation of test results, and most importantly, which values to use.

The relationship between results from the rapid chloride penetrability test (RCPT) as measured using AASHTO T 277 and diffusion coefficients calculated from ponding tests using AASHTO T 259 is quite good even though test conditions and ages are different.(1-3) If comparable curing and longer ages are used in each test method, the relationships can be improved. For example, Virginia Department of Transportation (VDOT)(4) has adopted accelerated curing of specimens consisting of one week at 73°F (23°C) and three weeks at 100°F (38°C) for the RCPT while extending the duration of the ponding test from 90 days to one year or more. It should also be noted that values of RCPT become lower with time. Consequently, the concrete age at time of testing is important.

The specified value of chloride penetrability should be selected based on the importance of the bridge element, the exposure conditions, expected service life, and practical achievability with acceptable materials. For example, lower values can be achieved more readily in precast, prestressed concrete beams than in cast-in-place concrete decks. Concretes containing only cement as the cementitious material may require very low water-cement ratios to achieve sufficient resistance to chloride penetration.(5) The resistance of concretes to chloride ion penetration increases with the use of latex, pozzolans (Class F fly ash, silica fume, or calcined clays), or slag.(6) Based on extended ponding tests, concretes made with these materials can have chloride contents at the depth of the steel reinforcement below the threshold value for corrosion initiation.

A penetrability value should be selected and a mix design developed to minimize cracking potential. For example, the use of a lower water-cementitious materials ratio as a means of reducing the penetrability of concrete results in a high strength concrete with a high modulus of elasticity and reduced creep. As a result, the deck concrete is more likely to crack from shrinkage, particularly if the concrete is not adequately cured.

Based on the above considerations, a maximum value of 2000 or 2500 coulombs at 56 days with standard curing represents a good starting point for bridge deck concrete. In harsher climates, lower RCPT values may be appropriate and should be considered. If test results at 28 days are required, accelerated curing may be specified. Selection of the specified values should consider the importance of the structural component, local experience, exposure conditions, curing of the test specimens, and achievable results.

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Answer contributed by H. Celik Ozyildirim of the Virginia Transportation Research Council at celik@virginia.edu or 434-293-1977.

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