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WESTMINSTER DRIVE UNDERPASS – ACCELERATED BRIDGE CONSTRUCTION USING GIGO (GET IN-GET OUT) BRIDGE CONCEPT

Mark D'Andrea, M.Sc., P.Eng.
Stantec Consulting Ltd., Canada

Wade Young, P.Eng.
Stantec Consulting Ltd., Canada

Andrew Turnbull, P.Eng.
Ministry of Transportation Ontario, Canada

ABSTRACT

The Ministry of Transportation Ontario (MTO), in partnership with consultants and contractors, developed a method for accelerated bridge construction called Get in-Get out Bridge or GiGo Bridge. The GiGo Bridge concept is an Accelerated Bridge Construction (ABC) technique for replacing bridges over freeways, in 45 days or less, with a full closure of the crossing road. The concept requires that bridge components be prefabricated in advance of the on-site work. This has the advantage of shifting a substantial portion of the work into the winter months, freeing up staff resources and equipment for the summer months. Additional benefits of GiGo Bridge include shorter disruptions to traffic as well as enhanced safety, since workers have less contact with traffic during the project.

In 2014, the Westminster Drive Underpass on Highway 401 in London, Ontario, was successfully replaced using the GiGo Bridge concept. The new, two-span integral abutment bridge consists of a number of prefabricated elements, including precast concrete abutments, wingwalls, and pier cap; and steel box girders. However, the accelerated bridge construction feature that is of primary interest in this project, and that is key to the GiGo Bridge concept, is the use of 6 prefabricated, 95-tonne supermodules, each of which consists of a steel box girder with a cast-in-place concrete deck.

Based on the success and lessons learned from the Westminster Drive project, MTO will be using the GiGo Bridge concept on other projects, including the replacement of the Highway 401/Highway 19 Underpass in Ingersoll in 2017.

Keywords: accelerated, prefabricated, supermodules, GiGo Bridge

1. INTRODUCTION

Infrastructure renewal has become a dominant theme across North America. Years of underfunding have resulted in a backlog of infrastructure needs that must now be addressed. As well, governments are planning to stimulate the economy by providing additional funds for infrastructure. Collectively then, the number of projects on our roads and highways will increase significantly, resulting in traffic disruption, delays and congestion. Not only does this affect peoples' lives and the economy through delays to the movement of people and goods, but the pollution created by idling vehicles will also increase. Our infrastructure could be renewed with much less impact on society, if projects could be completed much faster than in the past.

Many of the typical small to medium sized bridge replacement projects require one full season to complete. The construction duration doubles or triples when traffic on the bridge is maintained. What if this could be drastically reduced?

The Westminster Drive Underpass over Highway 401 in London, Ontario, Canada, was replaced, with Westminster Drive closed, in just 7 weeks. Using prefabrication techniques and “supermodules”, the impact on users of both Westminster Drive and more importantly, Highway 401, was drastically reduced. The success of the project validated the Ministry of Transportation’s Get in-Get out Bridge, or GiGo Bridge concept, and demonstrated that bridge replacement projects can be done, in many cases, with much less impact on the travelling public.

The GiGo Bridge concept is an Accelerated Bridge Construction (ABC) technique for replacing bridges over freeways, in 45 days or less, with a full closure of the crossing road. The concept requires that bridge components be prefabricated in advance of the on-site work. This paper discusses the evolution of the GiGo Bridge concept as well as the design and construction of the Westminster Drive Underpass replacement.

2. BACKGROUND

In 2011, the Ministry of Transportation, Ontario (MTO), West Region, identified that approximately 40 bridges on Highway 401, primarily underpasses, needed to be replaced in the next 20 years. These replacements can each take two years or more to complete if staged construction is carried out, resulting in many years of construction activity over and adjacent to Highway 401. Reducing the duration of these projects would be of significant benefit to the travelling public.

Short duration projects have the added benefit of increasing safety because the time during which traffic and construction are in conflict with each other is reduced. The duration of work carried out over or adjacent to Highway 401 could be reduced by prefabricating components outside the work zone, resulting in less driver distraction and enhancing worker safety. Shorter duration projects also reduce contractor overhead and Contract Administration costs.

2.1 Whiteman Creek Bridge

This bridge, located on Highway 24 south of Brantford, Ontario, was the project that set the stage for the GiGo Bridge concept. This was the first specifically designed ABC project in MTO West Region. Using local road detours, Highway 24 was closed for 7 weeks while the existing three-span concrete bridge was replaced with a single-span steel girder bridge (Young and Boparai 2013). Emerging materials, like Glass Fibre Reinforced Polymer (GFRP) and Ultra-High Performance Concrete (UHPC), were also incorporated into the project resulting in an innovative ABC solution.

2.2 GiGo Bridge Concept and Workshop

With the success of the Whiteman Creek Bridge in 2011, and the desire to replace bridges over Highway 401 with shorter construction duration, the GiGo Bridge concept was conceived, with the following goals:

- Interchange and underpass structure constructed in less than four months, with the crossing road closed for 45 days or less;
- Minimize work on and over Highway 401, which is one of the busiest highways in North America (reduce lane closures, lane shifts, detours and costs);
- Provide a safe work zone and increase public safety (reduce duration that workers and public are exposed to each other);
- Project costs similar to, or less than, traditional staged construction; and
- Scheme can be used at various locations (interchanges and flyovers) with minimal modification.

The Ministry developed a conceptual GiGo Bridge scheme and, with the assistance of Stantec Consulting Ltd. (Stantec), facilitated a workshop to present, confirm and refine the preliminary details. The initial GiGo Bridge concept was developed in advance of the workshop, using a prototype site at an interchange location. Workshop attendees included Ministry representatives, construction specialists, and design engineers from Stantec. The workshop, and a follow-up meeting with contractor representatives, resulted in several modifications and refinements to the preliminary concept.

The preferred GiGo Bridge concept included the following key elements:

- Four-span bridge configuration
- Piers founded on concrete caissons
- Integral abutments on a single line of steel H-Piles
- Cast-in-place pier columns with precast pier caps
- Precast concrete abutments and retaining walls
- Superstructure modules (supermodules), where each supermodule is comprised of twin steel I-girders and a cast-in-place concrete deck on the twin I-girders, or precast side by side concrete boxes with a conventional cast-in-place topping
- Cast-in-place deck closure strips, barrier walls, and approach slabs.

Recommendations were also made for a two-span bridge configuration for flyover sites.

Stantec and the Ministry prepared a GiGo Bridge report (Trader et al. 2012) that provides a flexible bridge replacement concept for use on future Ministry projects to complete underpass replacements in less than four months, with the crossing road closed for about 45 days. Armed with this report, a request to implement the concept immediately on an upcoming project was granted.

3. WESTMINSTER DRIVE UNDERPASS

The Westminster Drive Underpass, located in London, Ontario, needed to be replaced due to its age and condition.

The 28.8 m single-span rigid frame bridge, constructed in 1959, was comprised of three variable depth reinforced concrete box girders. This flyover structure carried two lanes of Westminster Drive over four lanes of Highway 401 traffic. The abutments were situated adjacent to the highway shoulders, within the clear zone, and would not allow for widening of the highway.

MTO determined that the bridge would be replaced using the GiGo Bridge concept. The spans for the new structure needed to accommodate future highway widening by providing full clear zones for an ultimate 8-lane configuration of Highway 401. Therefore, the design team determined that the new structure would consist of a two-span continuous integral abutment bridge with spans of 29.8 m each. This configuration required a pier situated in the median.

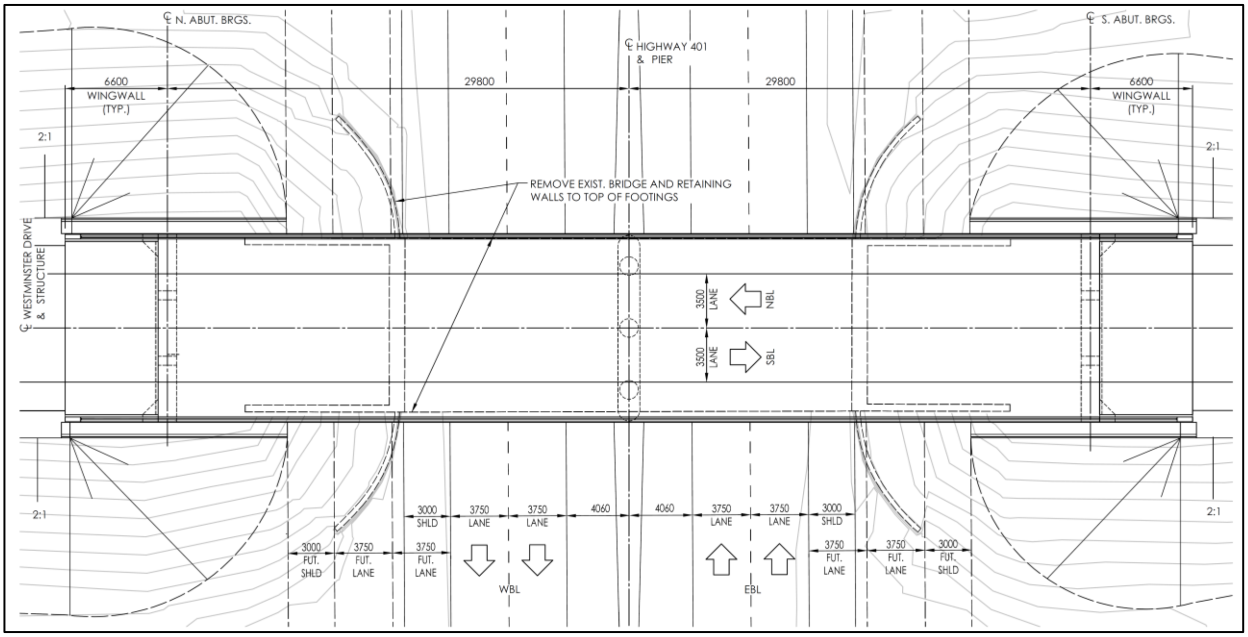

Figure 1: Westminster Drive Underpass – Plan

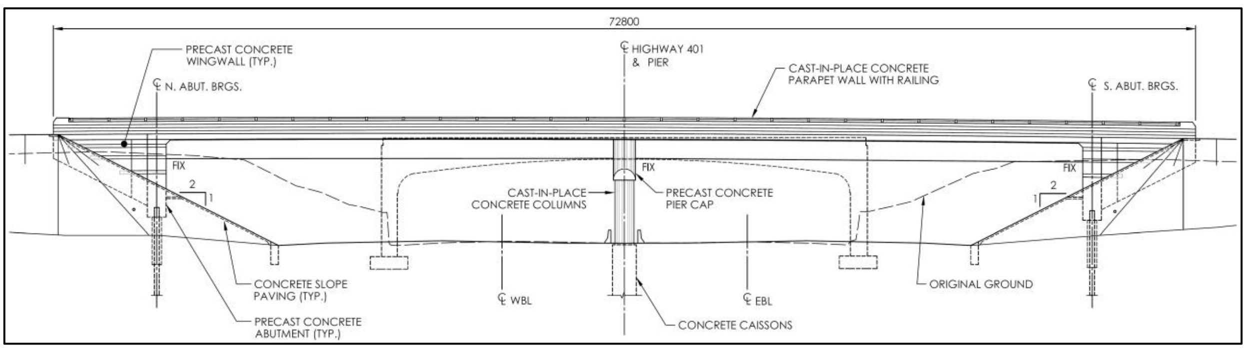

Figure 2: Westminster Drive Underpass - Elevation

3.1 Design Features

Two designs were prepared and tendered for this bridge; a precast concrete I-girder alternative and a steel box girder alternative. Steel box girders were selected in lieu of the steel I-girders recommended in the GiGo Bridge report in order to address MTO preference for box girders over highways; I-girders are more likely to have salt and debris collect on the top of the bottom flange. The steel box girder alternative was selected as the preferred superstructure type by the Contractor and is described below in further detail.

The 12.2 m wide cross-section of the new Westminster Drive Underpass consists of a slab-on-girder system made composite with a 225 mm cast-in-place concrete deck. Therefore, the supermodules consist of six 1200 mm deep steel box girders.

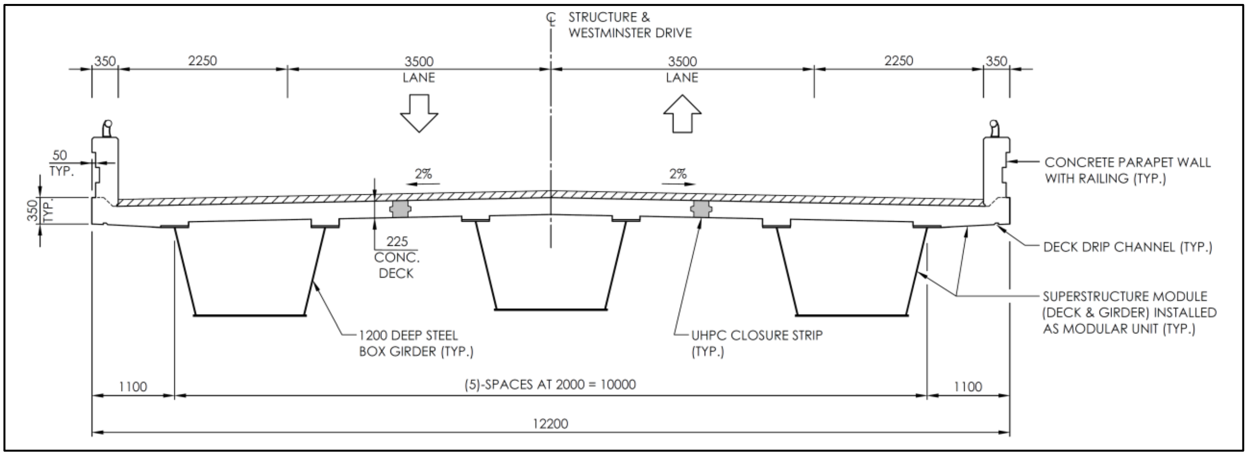

Figure 3: Westminster Drive Underpass – Cross-Section

The superstructure is simply supported for dead load but is continuous for live load. A transverse closure strip is used for the deck continuity connection over the pier. The pier diaphragm is integral with the pier cap.

The pier consists of a precast concrete pier cap resting on cast-in-place concrete columns, supported on concrete caissons. The integral abutments, supported on steel H-piles, consist of a precast concrete portion of the abutments below the bearing seat. The top portion of the abutment is cast integral with the ends of the deck.

3.2 Prefabricated Substructure Components

The prefabricated portion of each of the abutments consists of three equal width (3.65 m) precast concrete abutment stem segments and two precast concrete wingwall segments. The abutments, including all precast segments, incorporate horizontal relief stripes for aesthetic purposes.

Figure 4: Prefabricated Abutment Stem Segment

Figure 5: Abutment

Each 3.50 m tall by 1.20 m thick abutment segment has a mass of approximately 33 tonnes. Corrugated steel pipes formed voids in the abutment stem to allow for placement of the segment over the previously driven steel H-piles. High-early strength self-consolidating concrete (SCC) was used to fill the voids, bearing seats and closure strips between segments.

Each 5 m long by 0.45 m thick precast concrete wingwall segment is full height (i.e., extends above the bearing seat elevation to the bottom of the barrier wall elevation) and connects to the outside abutment segment via cast-in-place high-early strength SCC cleats. Horizontal ledges were added to the underside of the sloped portion of the wingwall to help with the installation and support of the precast wingwall segments. The mass of each wingwall segment is about 15 tonnes.

Figure 6: Pier Cap Installation

The prefabricated pier cap consists of a single 12 m long, 47-tonne precast concrete segment. The pier cap sits on three cast-in-place concrete columns. Each of the columns is founded on a drilled cast-in-place concrete caisson. There are ten 35M bars that extend from each of the columns and into 150 mm diameter CSP sleeves in the precast concrete pier cap. The precise location of the sleeves was provided on the contract drawings to accommodate pier cap shear reinforcing steel spacing. The contract required placement of the reinforcing steel in the columns to be carried out using a template built after fabrication of the precast pier cap to ensure proper field fit-up. Solid high-strength plastic shims supported the pier cap on the columns until the high-early strength SCC, used to fill the CSP sleeves and the gap between the pier cap and the columns, cured.

3.3 Supermodules

Three supermodules, consisting of a 1200 mm deep steel box girder supporting 4.0 m of concrete deck, are utilized for each span. The concrete deck portion started 900 mm from the centreline of the abutment bearings and ended 1400 mm from the pier centreline. Each 30 m long supermodule has a mass of approximately 95 tonnes.

Conventional concrete deck construction techniques were specified for the supermodule construction.

A temporary yard was used to build temporary substructures on which the steel box girders were placed. The temporary substructures had the same support conditions and bearing locations, including dimensions, cross-fall, superelevation and grade, as the new pier and abutments in the permanent location. After the steel box girders were installed on the temporary supports, the concrete deck was then formed, reinforced, cast and cured. The only difference of note was the use of block-outs at the transverse closure locations (at pier and abutments) and at the longitudinal closure strips (between each of the three supermodules in a span).

Installation of the supermodules on site required large cranes to lift the 95-tonne units into place. Highway 401 lanes needed to be closed in order to set up the cranes and to install the supermodules. A six-hour overnight closure of the eastbound lanes was permitted to complete the erection of three supermodules. Another six-hour overnight closure of the westbound lanes was allowed to place the other three supermodules the night after the eastbound lane closure.

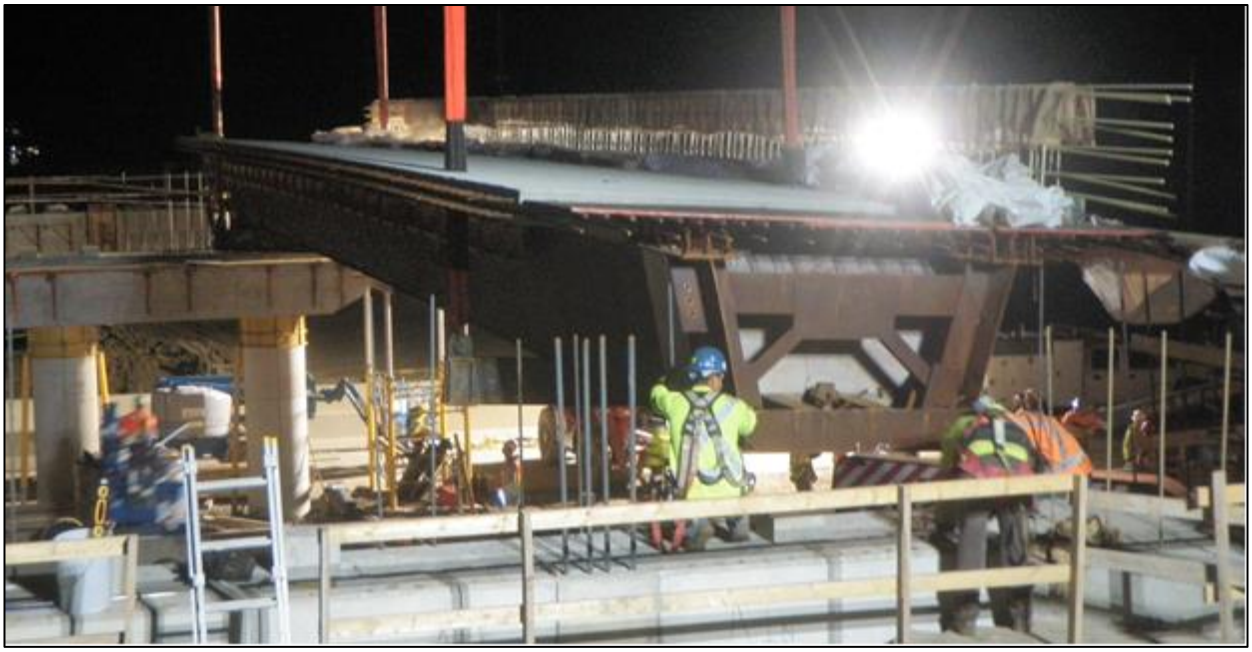

Figure 7: Supermodule Installation

Various options were investigated to achieve superstructure continuity at the pier. Casting of the pier diaphragm integral with the pier cap suited the GiGo Bridge concept best. This eliminated the need for field welding of steel plates, with their inherent future fatigue/durability issues. There was also no need for extensive reinforcing steel for a flex-link type joint. In order to ensure that the pier diaphragm was integral with the pier cap, dowels were installed through the bottom flange of the girder into the pier cap. The holes for the dowels in the steel girders and the pier cap were installed during fabrication of the applicable component. The ends of the bottom flange of the steel girders had additional stiffeners, including a transverse stiffener plate, to help transfer the compressive forces from the girder into the pier diaphragm.

Two 200 mm wide UHPC closure strips were used to fill the longitudinal gap between the supermodule units.

3.4 Construction

The contract for the replacement of the Westminster Drive Underpass was tendered in August 2013 and was awarded about one month later to Facca Inc. (Facca). Construction of the prefabricated bridge components began in January 2014. Fabrication of the abutment, wingwall and pier components was carried out at Facca's main yard.

Preparation of the temporary yard for the construction of the supermodules began early February 2014. The temporary yard was located only 7 km from the site. The steel box girders were delivered to the temporary yard at the end of February. The casting of the concrete deck for the supermodules was carried out in early May when temperatures were sufficient to complete the concrete casting and curing without cold weather protection measures.

The construction of the supermodules in the temporary yard achieved the GiGo Bridge goal of enhancing safety in the work zone by removing construction activities away from the highway. Construction personnel noted that forming and placing reinforcing steel for the supermodules was straight-forward at the temporary yard; there was easy site access, no traffic to deal with, and no concerns with dropping materials onto a roadway below.

Figure 8: Supermodule Construction in Temporary Yard

Work on-site commenced on May 26, 2014 and mainly consisted of field survey and median sewer relocation, which was necessary to accommodate median pier construction.

Westminster Drive was closed on July 2, 2014 and the majority of the existing bridge was removed the following Saturday night utilizing a 10-hour full closure of Highway 401. During the bridge removal, traffic was diverted onto an 11 km detour consisting of Highway 402 and Colonel Talbot Road.

The installation of the foundations and the prefabricated substructure components was completed in about 3 weeks. The steel H-piles had to be driven deeper than originally anticipated, requiring more pile length to be welded onto the originally supplied piles; however, the delay to the overall project schedule was only a few days. The construction of the abutments and pier, including the installation the prefabricated abutment components and pier cap, was carried out efficiently.

The supermodules were lifted onto transport trailers in the temporary yard using two large cranes (300-tonne and 500-tonne). The supermodule installation was completed during the nights of July 27 and 28, 2014. The westbound lanes of Highway 401 were closed for six hours the first night and the eastbound lanes were closed for six hours the following night. A 350-tonne crane was situated in the median for each of the six supermodule lifts. A 500-tonne crane was situated on the outside shoulder, near the north abutment for the three lifts for the supermodules in the north span and close to the south abutment for the other three lifts.

The Contractor placed formwork for the longitudinal closure strips on the supermodules prior to erection. After supermodule placement, the formwork was pulled up into place from the deck level, thus further reducing the work over Highway 401 and enhancing safety in the work zone.


Figure 9: Supermodule Installation

Although two night closures of Hwy 401 were required, the use of the supermodules was the key factor to achieving the goal of “reducing work on or over Highway 401” and “enhancing safety”. Once erected and secured, the use of supermodules ensures that installation and removal of formwork and installation of reinforcing steel over traffic is virtually eliminated. The superstructure is essentially 90% complete.

Completion of the superstructure construction (forming and casting of longitudinal closure strips, deck over pier, deck at abutments, parapet walls, and approach slabs) took approximately 3 weeks. Waterproofing and paving was subsequently carried out and Westminster Drive opened to traffic on August 22, 2014, 51 days after the road was closed. Median tall wall barrier reconstruction, concrete slope paving, application of concrete sealer, and site restoration concluded in early October.

Figure 10: Westminster Drive Underpass

The total contract price for the project was \$3.9 million; the bridge replacement cost totaling \$2.7 million (\$3,700/m^2). This bridge cost is only about 10% greater than other bridge replacement projects over freeways that use conventional construction techniques and staged construction to maintain traffic on the bridge.

4. CONCLUSIONS

The successful replacement of the Westminster Drive Underpass validated the GiGo Bridge concept developed by MTO. Utilizing prefabrication techniques and supermodules to replace this bridge over Highway 401 drastically reduced the impact to both roadway users and construction personnel compared to a conventional bridge replacement project. MTO will, therefore, use the GiGo Bridge concept for the replacement of the Highway 401/Highway 19 Underpass in Ingersoll in 2017 and other future projects.

The GiGo Bridge concept can be used as an ABC technique to deliver the large amount of infrastructure renewal projects expected over the next few years with fewer impacts to society.

ACKNOWLEDGEMENTS

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