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ABSTRACT

The North Shore Congregation Israel complex was designed by modernist architect Minoru Yamasaki and completed in 1964.

Yamasaki's notable work includes the Pacific Science Center (1962), World Trade Center (1971), and many other significant large scale projects. North Shore Congregation Israel exemplifies his early work, which included low-rise modernist structures with decorative concrete facades. Yamasaki was very interested in the design potential of precast and cast in place concrete and the materials versatility as both a structural and decorative material, as illustrated in this complex.

After several decades, spalling was observed along the edge of the architectural precast concrete panels. Previously installed concrete patch repairs were visually apparent and many were no longer serviceable. Wiss, Janney, Elstner Associates, Inc. was engaged to perform an assessment of the existing architectural precast concrete, document the extent and types of distress, and develop repair documents.

The paper will describe and illustrate the process of developing concrete repairs for North Shore Congregation Israel, including an overview of the assessment process and development of repair details, concrete cleaning procedures to address soiling and biological growth present on the building, and concrete mix design and finishing procedures to blend the repairs with the existing concrete.

KEYWORDS

Concrete; precast concrete; historic; modern; preservation; repair

Introduction

North Shore Congregation Israel is located on a bluff overlooking Lake Michigan in Glencoe, Illinois and consists of a complex of buildings designed by Minuro Yamasaki. Completed in 1964, a transition period in Yamasaki's career, the synagogue embodies the characteristics and architectural vocabulary of Yamasaki's early work including the use of concrete as a primary building material, a dynamic roof that defines the form of the building, architectural precast concrete panels that articulate the facade, and precast concrete shells that form a corridor to connect the building wings. Conservation of the architectural precast concrete included cleaning and repair of the existing concrete to address distress conditions and match the composition and finish of the original concrete. This article describes the process of evaluating the existing concrete and the collaborative

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design and construction process developed to ensure the success of the conservation project.

Minoru Yamasaki

Minoru Yamasaki (1912–1986) was an American architect of Japanese heritage perhaps best known for his design of the United States Science Pavilion (now the Pacific Science Center) for the Seattle World's Fair (the Century 21 Exposition, 1962) and the New York City's World Trade Center (1970–1971). The graceful concrete arched pavilion and the steel and glass skyscraper exemplified the elegance and functionality with which Yamasaki approached design; however, his body of work also conveys a dynamism and lightness that is best exemplified in his use of concrete. Particularly in his early work, Yamasaki explored the capabilities of precast concrete as a building material; it would become a primary palette for his designs. He used soaring tent-like roofs and decorative concrete facades to capture the 'serenity, surprise, and delight' that formed the core of his design principles.[1]

Yamasaki gained attention with his design of the Pruitt-Igoe Public Housing (1955) and Lambert Field Terminal (1956) in St. Louis, Missouri. Following completion of his early projects, Yamasaki chose to travel the world as a means of addressing his declining health. His later architectural work was influenced by his travels to France, Italy, Pakistan, India, Thailand, and Japan, and the buildings he saw there. Starting in the late 1950s, Yamasaki's work took on an aesthetic that came to be known as New Formalism. The first expression of this new aesthetic was the MacGregor Memorial Conference Center at Wayne State University in Detroit, Michigan (1958).

Yamasaki, along with Edward Durrell Stone, Welton Beckett, Marcel Breuer, and Philip Johnson were forerunners in New Formalism as an architectural style. The style is characterized by elements of Classical architecture such as symmetry, scale, columns with highly stylized entablatures and colonnades, and utilized rich materials such as granite, marble, and composite systems including architectural precast concrete. Design and construction with architectural precast concrete also allowed for distinctive and dynamic forms such as umbrella shells, parabolic arches, and folded plates. New Formalism, like other styles of Modernism, embraced concrete as a construction material because it was a cost effective, versatile, and ubiquitous material that could achieve the modernist design aesthetic.

Architectural precast concrete

Precast concrete developed as an exterior cladding material in the early twentieth century. The benefits of precast concrete included its fabrication in a controlled environment, allowing for better quality control and a more consistent product with refined architectural finishes. In addition, precast concrete units could be erected more quickly on site than cast in place concrete.

The development of precast concrete was aided by advancements in equipment to lift, transport, and erect precast concrete, as well as improvements to the concrete casting process. Schokbeton, a precast concrete system developed in the Netherlands in the 1930s, involved vibrating the concrete for a few minutes on a shaking table at the start of the curing process to consolidate the concrete. A well consolidated, dense, and higher strength concrete could be produced with less cement and water. Thus, thinner (and lighter) sections of concrete could be obtained that still met structural requirements.

Advancements in the appearance of concrete were led by the work of John J. Earley, beginning in the first decade of the twentieth century. Earley, who became known as 'the man who made concrete beautiful,' sought to create concrete that resembled stone by exposing the aggregate.[2] By the 1910s, Earley had developed a technique that included scrubbing some of the paste off before the concrete had fully cured, exposing the aggregate; he referred to concrete finished with this technique as *architectural concrete*. This type of concrete was used by Earley at Meridian Park in Washington DC (circa 1916–1940); Baha'i House of Worship in Wilmette, Illinois (1933–1943); and the Edison Memorial in Edison, New Jersey (1938). Earley consulted to the Dextone Company, a cast stone manufacturer, on construction of the David W. Testing Basin complex for the U.S. Navy at Carderock, Maryland, in 1938. The buildings were clad with exposed aggregate, precast concrete panels. Two years later, Louis Falco, Sr., of Dextone formed Mo-Sai Associates (later the Mo-Sai Institute), an organization of precast concrete manufacturers who specialized in the production of exposed aggregate architectural panels. The method of fabrication became known as the Mo-Sai process.[3] Research conducted by the authors has not revealed whether the precast concrete used at North Shore Congregation Israel was fabricated using the Mo-Sai technique.

North Shore Congregation Israel

The historic structures at North Shore Congregation Israel include a sanctuary, memorial hall, administration building, and school building connected by a shared enclosed corridor (Figure 1). An additional small sanctuary was designed by Thomas Beeby of Hammond, Beeby & Babka, Inc., and constructed in 1990 at the south end of the complex. Character-defining features of the buildings include the architectural precast concrete panels surrounding window and door openings, architectural precast concrete columns and roof shells that frame the glass corridor, and the cast-in-place concrete parabolic forms of the sanctuary. Yamasaki's design uses cast-in-place and architectural precast concrete to highlight the versatility of concrete as both a structural and decorative material. The precast concrete panels give the appearance of a pointed arch, reminiscent of Venetian Gothic architecture.

The architectural precast concrete has an exposed aggregate finish and was manufactured by the Superior Cast Stone Company of Sussex, Wisconsin. The panels range from 114 mm (4-1/2 inches) to 203 mm (8 inches) thick, depending upon their location, and have 16,0 (No. 5 US) mild steel vertical reinforcing as well as welded wire mesh reinforcing. The pointed arch form is enhanced by a raised profile along the edge of the panels. The raised perimeter edge projects approximately 76 mm (3 inches) from the face of the panel and is 70 mm (2-3/4 inches) wide, with 16,0 (No. 5 US) vertical reinforcing bar with 25 mm (1 inch) minimum cover (Figure 2). The precast element is anchored to the concrete structure with 16 mm (5/8 inch) diameter bolts in a structural concrete insert.

After several decades, cracking and spalling were observed along the edge of the architectural precast concrete panels at the school and administration buildings as well as at the memorial hall. Previously installed concrete patch repairs had been performed with

Figure 1. The parabolic arches of the sanctuary and the pointed arch pattern in the precast concrete panels embody the characteristics of Yamasaki's early work. *(Photo courtesy of Harry J. Hunderman, FAIA)*.

various levels of success in regard to appearance and durability. Some repairs appeared to have been installed with formwork while other repairs appeared to have been troweled with aggregate pressed into the face.

Assessment and investigation

The field investigation of the architectural concrete included a visual assessment as well as various types of nondestructive testing, inspection openings at areas of deterioration, and removal of concrete samples for laboratory studies. Nondestructive evaluation provides information regarding the location of reinforcement, properties of the concrete, and the location and extent of distress. Selective inspection openings were also used to confirm the findings of nondestructive evaluation. Locations for inspection openings were representative of the various conditions noted during the survey and were unobtrusive if possible.

At North Shore Congregation Israel, a visual survey was performed to document existing distress conditions. Observed distress included cracking along the raised profiles at the perimeter of architectural precast concrete, as well as previous trowel-applied cementitious patch repairs, indicating that distress at these locations was a chronic issue. Nondestructive tests, including careful tapping of the concrete with a sounding mallet, were performed to evaluate the type and extent of distress. Sounding indicated delaminated concrete and debonding of previous concrete patches that extended beyond the areas of visually apparent cracking. Inspection openings were created at areas of unsound concrete and debonded previous patches, which were removed at selected locations. The

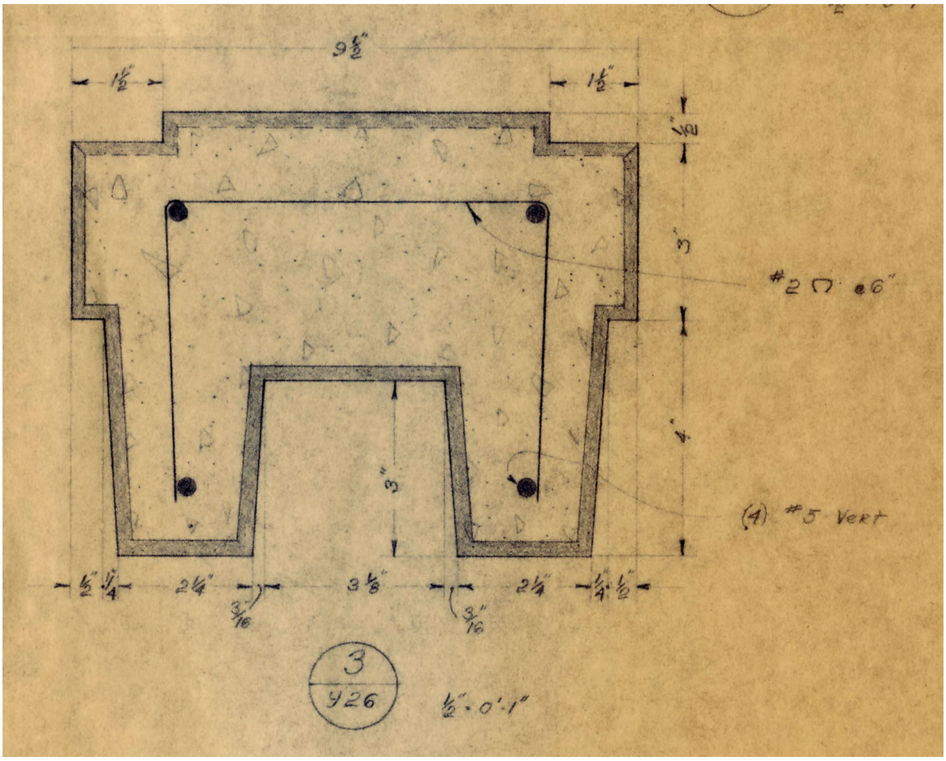

Figure 2. A detail from the precast concrete shop drawings of a typical column at North Shore Congregation Israel. *(Image of courtesy of North Shore Congregation Israel)*.

underlying reinforcing steel exhibited corrosion product and at some locations there was evidence of organic growth. Examination of inspection openings also revealed that cementitious patch material had been applied without removing the original concrete around and below the reinforcing steel.

Laboratory studies

Laboratory studies provided information on the characteristics of the concrete and causes of deterioration. The geometry and thicknesses of the precast panels created some challenges in obtaining samples. Fragments or incipient spalls were therefore used as concrete samples for laboratory analysis. Generally, information obtained from such fragments needs to be considered in light of the exposure of such material to outside environmental contaminants such as biological growth, atmospheric soiling, and other organic debris that can impact the interpretation of the test data.

Petrographic examination following BS 1881-211:2016 *Testing Concrete Procedure and Terminology for the Petrographic Examination of Hardened Concrete* (ASTM C856, *Standard Practice of Petrographic Examination of Hardened Concrete*), the detailed analysis and study of concrete using stereomicroscopy, provided valuable information to assist in identifying the causes of distress and in the developing a concrete repair design. The precast concrete at North Shore Congregation Israel was identified as having white portland cement with a crushed quartzite aggregate and multi-colored rounded quartz sand fine aggregate. There were microfractures, shallow fissures, in the cement at the surface of the concrete that appeared to be interconnected and were observed to contain biological growth.

Chemical analysis was performed to identify the presence of chlorides, sulfates, and other elements in the concrete that may contribute to deterioration. Water-soluble chloride analysis was performed in accordance with ASTM C 1218, *Standard Test Method for Water-Soluble Chloride in Mortar and Concrete*. Two of the three samples collected at North Shore Congregation Israel were measured to have elevated levels of chloride in the concrete. Studies have shown that elevated levels of chloride content in concrete can promote corrosion of embedded steel in the presence of sufficient moisture and oxygen.

Mechanisms of distress identified during the assessment and investigation and laboratory analysis included corrosion of the embedded mild reinforcing steel. The deterioration of the embedded steel was likely accelerated by water infiltration through microfractures at the face of the concrete and insufficient concrete cover at the raised perimeter edge of the panels.

Approach to design

Distress at the architectural precast concrete panels was consistently observed at the raised perimeter edges of the panels, which have a narrow profile, measuring 63 mm (2-1/2 inches) wide, and minimal concrete cover at the reinforcing steel. The distress appeared to align with the location of the vertical reinforcing steel. Repair details were developed that considered technical performance issues while maintaining the profile of these features and managing aesthetic considerations.

Concrete repairs using formwork are preferred to trowel-applied repairs, primarily for durability. Concrete repair materials with coarse aggregate, utilized in formed concrete repairs, will have characteristics more similar to those of the substrate concrete than trowel-applied repairs, and the formwork will allow for proper consolidation of the repair. The difference in performance between formed and trowel-applied concrete repairs is evident in the previously performed patches at North Shore Congregation Israel. Formed patches appear to be a better physical match to the existing concrete and are generally in fair condition. Trowel-applied patches, on the other hand, are more visually apparent and more often exhibit cracking, spalling, and indications of debonding.

In addition to the installation approach, proper surface preparation is important to the long-term durability of the repairs. At North Shore Congregation Israel, preparation of the substrate included removal of all unsound concrete material and cleaning of the embedded steel to achieve bond of the repair material to the original concrete substrate. Repair details included the removal of concrete to access all sides of the corroded reinforcing steel, extending into sound historic concrete where needed. Once exposed, ongoing corrosion of the reinforcing steel was mitigated by abrasive cleaning of the reinforcing steel and application of a corrosion-inhibiting coating (Figure 3). Exposure of all sides of the reinforcing bar also allowed concrete repairs to key in and mechanically anchor to the substrate concrete.

Figure 3. Preparation of the substrate included removal of sufficient concrete to expose all sides of the reinforcing steel, which was then abrasively cleaned and coated. *(Photo courtesy of Paul Gaudette, FACI)*.

Repairs to the concrete have the potential to impact the overall appearance of the building, especially if joints between original concrete and patch materials are easily discernible. To minimize this potential impact, concrete repairs at North Shore Congregation Israel were designed so that the edges of repairs aligned with changes in plane in the precast concrete. With this approach, the joints between the existing concrete and the repairs could be concealed by shadow lines and interior corners that were less visually apparent.

Development of repair procedure

The concrete repair procedure was developed through a repair design process that included development of a mix design followed by concrete trials and mock-ups. This process established the technical performance and overall aesthetic of the repairs. The success of the repair process was dependent not only on the design, but to a great extent on the experience and skill of the craftsman performing the work. The process of concrete mix design, trials, and mock-ups was a collaborative effort through which the contractor, design team, and owner were able to confirm the developed conservation approach, refine the repair process, establish a standard of workmanship for the project, and review and evaluate examples of the completed repair.

Development of a concrete repair mix is a challenging process and benefits from participation by a skilled and experienced craftsman. From the petrographic examination, the design team identified the cement and was able to characterize the coarse aggregate and sand for the precast concrete at North Shore Congregation Israel. For some concrete repair projects, locally available materials may have been used during original construction and may be available for repairs. However, in some cases original materials may not be available, or aggregate currently available from the same quarry may be obtained from a different depth or location that does not necessarily match the original constituents. At North Shore Congregation Israel, where the original precast concrete panels were fabricated off-site at a facility approximately 161 kilomtres (100 miles) away, research was required to find a similar coarse aggregate and sands that met technical performance requirements. Mineral pigments and admixtures can be considered to achieve a color match; however, the durability and color stability of the materials needs to be understood.

Developing a concrete design mix, including review and approval, can be a lengthy process. Concrete samples require sufficient time to cure before the aesthetics can be evaluated, and construction schedules often do not allow appropriate time for this process. At North Shore Congregation Israel, development of the concrete mix design was performed as part of the repair design process, prior to bid. This was especially beneficial because some of the concrete components, such as the aggregate, were difficult to source. This approach also provided time often not allotted for during construction and allowed the project team to develop detailed technical specifications, citing the specific design mix, for contractors to reference during the bidding process.

The architectural precast concrete at North Shore Congregation Israel had biological growth and atmospheric soiling that had accumulated over the building's more than fifty years of service life. Soiling was concentrated at the recessed areas of cement paste and affected the overall appearance of the precast concrete. Cleaning of the concrete was required to provide a clean surface for matching the concrete repair mix and prior to repair installation, as well as to improve aesthetics. Cleaning trials were performed to evaluate the most appropriate methods to remove surface soiling and staining. Trials included a range of chemical cleaning products, including mild detergents and biocides, and provided an opportunity to evaluate their effectiveness on various substrate finishes and orientations, environmental conditions, and degree of soiling. In general, the objective of cleaning is not to restore the concrete to its original appearance, but rather to remove the soiling and staining to the extent possible without damaging the concrete. For concrete repair projects, where the new concrete patches are intended to match the original, the cleaned concrete should have a consistent level of appearance to which concrete samples can be matched. The gentlest effective cleaning should be selected for use.[4] In some cases, more than one system may be needed. At North Shore Congregation Israel, a biocide cleaner was used, as it was able to treat the biological growth within the recesses and microfractures in the concrete, as well as to remove some of the atmospheric soiling.

Once the materials in the original concrete mix design had been identified, off-building trials were performed to evaluate the concrete mix design and finishing techniques. Samples, measuring approximately 305 mm by 305 mm (12 inches by 12 inches), were fabricated by the contractor that represented a wide range of concrete mix proportions and finishing techniques (Figure 4). The off-building trials incorporated different proportions of cement, large aggregate, and sand. Various finishing techniques were also

Figure 4. Off-building samples were fabricated to evaluate the concrete mix design and surface finish for comparison to the existing precast concrete on the building. *(Photo courtesy of Mike Ford, AIA).*

evaluated to assist in identifying a finishing process that replicated the existing. The proportion of large white coarse aggregate to the multi-colored sands impacted the overall appearance of the concrete as did the texture of the exposed concrete finish. The off-building trials were used to refine the proportions between materials in the concrete mix design, and to develop procedure for finishing the concrete to match the appearance of the existing cleaned but weathered concrete, without resulting in unacceptable repairs on the building that would require removal.

The size of the trials allowed the project team to easily handle and transport the samples and evaluate them against different locations on the building, including a range of building components and lighting conditions. Because of the nature of the exposed aggregate, the various natural lighting conditions significantly affected the visual appearance of the trials as compared to the existing concrete.

Once successful trials were approved, staged mock-ups were performed on the building to evaluate repairs in the field. Selected mock-up areas should represent typical distress conditions that will require repair and should be located at areas on the building that are easily accessible, to allow for execution and review of work, yet not visually apparent. At North Shore Congregation Israel, an area of spalling at the lower level on the back elevation of the building was selected. The mock-ups were performed so that every stage of the repair process could be evaluated, including cleaning of the concrete, preparation of the substrate, application of the formwork, installation of the concrete repair, and finishing of the concrete (Figure 5). The mock-ups also assist in evaluating

Figure 5. As part of the mock-ups, each step of the concrete repair process was evaluated, including the formwork and finishing techniques. *(Photo courtesy of Paul Gaudette, FACI)*.

the constructability of repairs and challenges that will be faced in repair implementation. The curved forms of the precast concrete panels at North Shore Congregation Israel presented a challenge in terms of the installation of formwork. The contractor created plywood forms that were scored on the backside, bent in the field to match the contours of the repair area, and secured in place with clamps (Figure 6). There were also challenges with developing a consistent and constructible procedure for finishing the concrete. Through the process of trials and mock-ups, a system was developed where a retarder was applied to the formwork prior to installation of the concrete repair mix. After approximately 24 hours of concrete cure, the forms were removed and the concrete was hand brushed to expose the aggregate to a depth that resembled the existing concrete adjacent to the repair area. Mock-ups allowed the project team to work though complicated conditions and develop a repair approach prior to implementing repairs throughout the whole building (Figure 7).

Repair implementation

Following approval of the mock-ups, the contractor continued with the concrete repairs using the procedures established during the repair design and development process. The work included cleaning of the concrete followed by selective demolition of unsound concrete, preparation of the repair area and reinforcing steel, installation of the concrete

Figure 6. During the mock-ups, a process was developed for shaping the formwork around the curved contours of the concrete. *(Photo courtesy of Mike Ford, AIA)*.

repair material, finishing, and application of a penetrating sealer. During implementation of the concrete repairs, craftsmanship should be maintained at a high level to achieve an acceptable final result. One way in which this standard of quality was maintained at North Shore Congregation Israel was through the involvement of a skilled foreman who contributed to the development of concrete repairs during the trials and mock-ups, and was able to convey and establish a quality of work from his crew in the field.

The design team performed regular site visits throughout construction to evaluate selective demolition at repair areas, preparation of the reinforcing bar, installation of the formwork and concrete patches, and finishing. The design team also observed the batching and mixing process to confirm that the concrete was being mixed in accordance with the mix design development. Slump, air content, compressive strength, and other tests were also performed. In addition, hammer sounding was performed at repairs, once they had adequately cured, to detect any areas of unsound or unbonded repair materials. Because of the exposed aggregate finish, rubber mallets were used to ensure that the sounding did not damage the concrete finish. Repairs that deviated from the approved mock-ups, were unsound, or did not match the adjacent concrete, were either modified or removed and replaced, as appropriate for the condition. Although repairs that required further attention were limited, at a few locations completed repairs were not successful. For example, placement and consolidation of concrete at the top of the formwork is usually challenging and require hand placement techniques prior to installing the closure piece for the wood form. Small gaps were present

Figure 7. An example of the completed repairs at a window perimeter, showing the successful match of the repair to the original exposed aggregate precast concrete. *(Photo courtesy of Mike Ford, AIA)*.

between the patch and existing concrete that required additional patch material or were inadequately finished.

Upon completion of the project, a clear penetrating silane-based sealer was applied to the concrete to reduce water penetration. The use of the concrete surface sealer minimized the amount of water penetrating the concrete, while also allowing moisture in the wall system to escape. A sealer was used at North Shore Congregation Israel to afford additional protection for the steel reinforcement in areas where concrete cover was limited due to the narrow profiles of the precast elements. Trial applications were performed to evaluate the efficacy of the sealer, as well as to confirm that it would not affect the appearance of the concrete.

Conclusion

The themes and characteristics of Yamasaki's early works are fully envisioned in his design of North Shore Congregation Israel through his use of dynamic and decorative forms constructed of cast-in-place and architectural precast concrete. Our role as conservators and stewards of the built environment is to recognize, appreciate, and interpret our historic resources. At North Shore Congregation Israel, the concrete conservation work – realized through a collaborative design development and repair implementation process – has restored the 'serenity, surprise, and delight' for which Yamasaki strived in his designs.

Notes

1. Dale Allen Gyure, *Minoru Yamasaki: Humanist Architecture for a Modern World* (New Haven, CT: Yale University Press, 2017), 260.
2. Frederick William Cron, *The Man Who Made Concrete Beautiful: A Biography of John Joseph Earley* (Fort Collins, CO: Centennial Publications, 1977), 28.
3. Sidney Freedman, 'History of Exposed Aggregate (Mo-Sai) Architectural Precast Concrete', *PCI Journal*, May–June 2004, 22–33. Earley's work was often referred to as a 'concrete mosaic,' hence the name 'Mo-Sai.'
4. Paul Gaudette and Deborah Slaton, *Preservation Brief 15: Preservation of Historic Concrete* (Washington, DC: U.S. Department of the Interior, National Park Service, 2007).

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No potential conflict of interest was reported by the author(s).

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