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Back to the future— Alexandria's new world library

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The works of Euclid and Archimedes are known to us today thanks largely to the fact they were referenced in the world's first international library. The Great Alexandrina Library on Egypt's Mediterranean coastline flourished for nearly 600 years before being destroyed in 272 AD. Last month, April 2002, nearly two millennia later, it was finally replaced with a stunning new £150 million structure that boasts the largest ever reading room and an 18 m diameter spherical planetarium. The vast 160 m diameter concrete building is cast monolithically within the world's biggest circular diaphragm wall. The new Bibliotheca Alexandria also features the largest contemporary stone sculpture—a 6200 m² hand-carved granite façade depicting all known forms of writing—and serves as a showcase for technical innovations such as ultra sonic pile monitoring and self-repairing concrete.

It was under the Ptolemaic dynasty that the city of Alexandria in Egypt started to dominate the eastern Mediterranean culturally, politically and economically. It heralded a 900-year golden age for the citizens of Alexandria and Egypt, so much so that the city became known as the 'queen of the Mediterranean'. In addition to its strategic location between Europe and Africa, the city's fortunes were also built on its monopoly of the papyrus industry for the entire Mediterranean.

Alexandria's existence began shortly after 331 BC, when Alexander the Great crowned himself Pharaoh in Memphis and built an eponymous fortified port. He connected the island of Pharos, located in the centre of the bay, to the mainland by a 1300 m long causeway called the Heptastadion. This later led to the creation of Alexandria's two harbours and the Pharos lighthouse, one of the seven wonders of the ancient world. Following Alexander's death, one of his generals—Ptolemaios Soter—took Egypt as his share in the division of Alexander's empire. He became the first Pharaoh in the last dynasty that was to rule Egypt until the death of Cleopatra VII in 30 BC. The Ptolemaic dynasty's success is due to the fact

that he and his descendants wholeheartedly adopted the Egyptian way of life.

World's greatest library for six centuries

In 320 BC, Ptolemy I decided early in his reign to change Alexandria from being just another port into his capital. He also decided to make it a home for science and art by creating a great library that gathered together all the cultures and civilisations known at that time. The exact site of the Great Alexandrina Library still remains to be found but it is believed, due to its connection with the museum, to be located in the Brucheion, the royal quarter in the northwest of the city (Fig. 1).

Ptolemy I invited scholars and artists from all over the known world to come and take up the challenge of promoting

Fig.1. An eighteenth century map of ancient Alexandria showing the two circular harbours and the walled royal quarter where the ancient library was thought to be situated

“The new complex—which has the world’s largest reading room—lies almost on the same site as its predecessor”

learning. In 296–295 BC he gave the job of organising the library to Demetrios Phalereus, a student of Aristotle (who was in exile in Alexandria after ruling Athens) and tutor to Ptolemy I’s heir. In the ‘Letter of Aristaeas’, it states

Demetrius...had at his disposal a large budget in order to collect, if possible, all the books in the world...to the best of his ability, he carried out the Pharaoh’s objective.¹

Ptolemy II Philadelphus (282–246 BC) completed the library’s work and its connection to the museum, both of which were located within the royal quarter. The library was open to all those who could read and who wished to learn, and consisted of collections of papyrus scrolls.

Ptolemy III wrote a letter ‘to all the world’s sovereigns’ asking to borrow their books. He even instructed that any cargoes of books on ships docking at Alexandria were to be seized and the term ‘ships’ libraries’ came to be known for books housed in the museum. The library then made copies of the books and gave the copies to the ships’ masters, keeping the originals in the library.

The first librarian was Zenodotus. He was succeeded in 245 BC by Callimachus of Cyrene, Alexandria’s most famous librarian, who created for the first time a catalogue of the scrolls. Several centuries later, John Tzetzes records that Callimachus catalogued 400 000 ‘mixed’ scrolls (those that contained more than one chapter, work, or even author), 90 000 ‘unmixed’ scrolls and an additional 42 000 scrolls in the Serapeum or ‘daughter library’, which was built during Ptolemy III’s reign (246–222 BC).²

A major loss was suffered two centuries later, when, in 47 BC, Caesar was compelled to set fire to his fleet in order to prevent it falling into the hands of the Egyptians. The fire spread to the docks and the naval arsenal, and destroyed 400 000 scrolls. However, it is presumed from a statement made by Orosius that the scrolls were not in the library but had been removed for shipment to Rome.³ This loss was partly made up six years later by Anthony’s gift to Cleopatra in 41 BC of 200 000 vol-

Fig. 2. View of the new Bibliotheca Alexandrina complex

umes from the library of Pergamon.

However, after nearly 600 years as the world’s greatest library, the main building and museum are thought to have perished when the greater part of the Brucheion was destroyed under Aurelian in 272 AD. The daughter library is believed to have survived for a further century or so, but probably perished when Theophilus (391–415 AD) destroyed the Temple of Serapis.

New library aims to revive past glory

In April 2002, some 1700 years later, the New Bibliotheca Alexandrina was officially opened in Alexandria with the aim of reviving the city’s past cultural glory (Fig. 2). The new complex—which has the world’s largest reading room—lies almost on the same site as its predecessor, adjacent to the ancient royal quarter. It gives modern expression to an ancient endeavour, providing unrivalled in-house and on-line access to researchers and readers all over the world.⁴

The idea for reviving the library came from the University of Alexandria in 1974 and, in 1987, the project won the support of president Mubarak. The International Union of Architects (UIA) in cooperation with the Egyptian government and the United Nations Educational, Scientific and Cultural Organisation (UNESCO)⁵ organised an ‘open’ international design competition in 1989. This was won by Snøhetta of Norway, which in a joint venture with Hamza Associates of Egypt, was then

awarded a design and construction supervision contract in 1993.

Most of the funding for the £150 million project has come from the Egyptian government, while UNESCO has provided technical support. The foundation works were carried out by a joint venture of the Rodio Group, Lodi, Italy; TREVI Foundation Specialists, Cesena, Italy; and Arab Contractors, Cairo, Egypt. The superstructure construction was undertaken by a joint venture of Arab Contractors and Balfour Beatty. Work started in mid-1995 and was substantially completed by December 2000. Following the installation of 200 000 books, the complex was officially opened on 23–25 April 2002.

Designed for up to eight million volumes

The new complex is located alongside the ancient eastern harbour of Alexandria and is directly adjacent to the university. The project consists of three structures

- the library building
- the planetarium
- a footbridge.

The library building has four basement levels and six floors under the highest point of its dramatic sloping roof (Fig. 3). It is designed to contain eight million volumes of books, audiovisual media, maps, and rare manuscripts, as well as books on compact electronic storage systems. The overall diameter of

Fig. 3. Longitudinal section of the new library building, which has eleven floors at its highest point

the visible structure is 160 m and its height above street level is 32 m. Table 1 provides details of the floor areas.

A shallow pool surrounds the library, providing a horizontal surface to complement the tilting roof line (Fig 4). A large open plaza connects the main entrances of the library and an existing conference centre. The plaza, which is freely accessible to the public, includes a suspended spherical planetarium. A footbridge across the plaza links all parts of the complex to the neighbouring university campus.

Architectural design reflects rich history

The library's circular, tilted form helps it to blend in with its historically rich location adjacent to Alexandria's circular harbour. The eleven floors are contained in a tubular envelope with an ovular cross-sectional plan. However, because the axis of the tube is tilted at an angle of 8.04° to the vertical, the horizontal floor plate and 16.08° sloping roof form true circles. The reading room is set onto 14 half levels giving it the appearance of a giant amphitheatre (Fig.5). There are

Fig. 4. Helicopter view of the new complex, showing the circular library, spherical planetarium and interconnecting footbridge

Table 1. Floor areas

	Area: m ²
Project areas	
Site area	45 000
Gross area of building	85 405
Function areas	
New library	55 000
– open library floor areas (one hall)	20 170
– enclosed book storage	18 000
– operational support	3625
Administration	2000
International school for information studies	3500
Cultural activities	4000
Planetarium (99 people)	3500
Science museum	1440
Antiquity museum	900
Meeting rooms	3200
Public car park (140 cars)	7000
Staff car park (54 cars)	2100
Auxiliary functions	5800
Existing conference centre (3000 seats in total)	30 840

Fig. 5. Cut-away graphic of the library showing: (a) reading room with main book storage below; (b) viewing platform; (c) restaurant; (d) public entrance; (e) offices and ancillary spaces; (f) existing conference centre; (g) high-level walkway; and (h) Corniche road

“The diaphragm wall is 160 m in diameter and is thought to be the largest circular diaphragm wall ever built”

Fig. 6. Interior of the world's largest reading room, with a floor area of 20 170 m²

two enclosed study rooms providing space for groups of up to 60 people.

The height of the columns in the reading area ranges from 6 to 17.5 m. The combined reading areas accommodate 550 carrels—2000 seating areas in total. Circulation is accommodated within the ‘spine’ of the building that runs longitudinally from one end of the circular plan deep into the reading areas. The geometry of the building is generated primarily by the functional arrangement of bookshelves and reading desks into identical structural bays measuring 14.4 x 9.6 m (Fig. 6). Indirect natural light flows through the north-facing vertical skylights in the roof. A state-of-the-art air conditioning, ventilation and fire suppression and smoke exhaust system add to the safety and comfort of the reading areas, while all public areas are fully accessible to the disabled. At the same time, the security of the contents of the building has been preserved.

The exterior façade consists of nearly 6200 m² of hand-carved stone and represents the largest contemporary sculptural edifice in the world (Fig. 7). The carvings are taken from all known alphabets and symbols of the world, past and present, and also includes future projections.

Built within a 160 m diameter diaphragm wall

The library building is supported on a tension/compression piled raft (Fig. 8). Single- and double-belled shaft and base grouted bored piles were used. The groundwater level—0.9 m above sea level—is 11 m above the fourth basement slab level. Earth and water retention to the deep substructure was provided by means of a diaphragm wall. This wall extends to the sandstone at a depth of 35 m.

The diaphragm wall is 160 m in diameter and is thought to be the largest

Fig. 7. The exterior façade consists of 6200 m² of hand-carved granite panels depicting examples of all known forms of writing—the biggest contemporary sculpture in the world

circular diaphragm wall ever built. It is designed to have continuity of horizontal reinforcement, resisting earth, seismic and water pressures by ensuring the development of hoop stresses. The adjacent conference centre was so close that the diaphragm wall had to be truncated into a straight line on the western side. This straight section was designed using a sequence of cantilever T-sections that contained horizontal continuous reinforcement and that were post-tensioned to avoid tensile cracking.

Geotechnical works were performed from the working platform that was 3–4 m below street level. The horizontal and vertical waterproofing of the underground surfaces were obtained by two lines of defence—high density polyethylene sheets jointed by welding, and a special waterproofing liner made of dry bentonite sandwiched between geotextile fabrics.

Two circular parallel reinforced concrete walls were incorporated into the construction to resist lateral loading associated with wind, earthquake and stability forces. These are additional walls inside and above the diaphragm wall. The outer of the two walls carries vertical loading and is capable of resisting groundwater pressure during the 200-year life expectancy. It extends to ground level and is separated from the diaphragm wall by a continuous drained waterproof membrane. It is also

restrained by the floor construction and counterfort cross walls linked to the inner wall. The inner wall is in the form of a partially sunken cylinder, and extends to 32 m above ground level at its highest point, which creates a circular plan shape and supports the carved granite-cladding panels.

Sloping north-facing roof avoids direct sunlight

The absence of direct sunlight into the library is of paramount importance to the welfare of the books and to the comfort of the readers. The roof of the library slopes at 16.08° to the horizontal

and faces north towards the sea. It is divided into rectangular bays by long-span reinforced concrete simply supported beams (Fig. 9). The slope of the roof enables these bays to rise by a series of 4.15 m high stories.

To support the roof bays, the slender circular concrete columns expand into elegant conical capitals (Fig. 10). The most slender columns are 16.5 m long and 700 mm in diameter. Each roof bay is filled with aluminium and steel panelling with a vertical glass step running diagonally across it, i.e. at 45° to the north (Fig. 11). The roof bay also provides horizontal movement restraint to the columns.

“The project combines and implements a wide range of innovative techniques and methods”

Fig. 12. Steel structure of the planetarium is supported over a 24 m wide basin by two steel lattice bridges

Fig. 13. The 18 m diameter planetarium is clad with glass-fibre reinforced concrete panels separated by light bands

The library superstructure consists of a reinforced concrete frame comprising a flat floor of 400 mm deep waffle floors with ribs at 1000 mm centres spanning to central beam strips 400 mm deep to columns and walls at 7.2 m and 9.6 m centres. At lower floor levels, where heavy live loads are applicable, the floor construction becomes 600 mm deep waffle floors with corresponding 600 mm deep beam strips.

One of the mechanical and electrical design requirements was that library users should not see anything of the services. The air-conditioning ductwork runs up a 700 mm gap behind the internal wall cladding and inside channels cast into the roof beams. The electrical power cables are passed into galvanised steel sheets cast beneath the floor screed.

Planetarium—an 18 m diameter steel ball

Positioned outside the library, the spherical planetarium and science museum are set into a public plaza and open to the public even when the library is closed. They are connected to the surroundings by a bridge from the university campus, through the library, and passing over the planetarium itself towards the beach.

The planetarium is made from an 18 m diameter steel ball structure suspended above a 24 m by 24 m concrete basin on two simply supported steel lattice bridges (Fig. 12). Its shape was inspired by the first images of the earth as seen from the moon. The ball is covered with glass-fibre reinforced concrete panels separated by light bands (Fig. 13).

A unique and innovative project

The new Bibliotheca Alexandria is a new generation of building, the like of which has not been seen before. The project combines and implements a wide range of innovative techniques and methods that make it attractive both for designers and for engineers.

The designers have had to overcome some considerable engineering design challenges

- the library houses the largest reading room in the world—an area of 20,000 m²

- the 160 m diameter diaphragm wall is the largest unsupported circular diaphragm wall in the world, with 14 m of unsupported free excavation
- the wedge-shaped building has an inherent overturning moment—there are large permanent uplift forces on the thicker side, which penetrates 12 m below the groundwater table
- to maintain rigidity, the library building has no joints for expansion or contraction
- air conditioning is needed for huge areas with no ceiling
- a state-of-the-art fire detection and protection system is required to preserve the unrivalled collection of invaluable ancient manuscripts
- the building is required to have a 200-year life expectancy.

The designers also had to take into consideration the architectural and serviceability requirements. Because the shelves run on rails, the design required zero differential settlement—which meant there had to be 'zero' deflection over the spans of the floor beams. A dynamic three-dimensional, finite-element analysis of the whole structure was therefore carried out to ensure this.

Some advanced technologies—especially for the bored piling, diaphragm walling and roof construction—were adopted for the first time on a large scale and verified under a strict quality control system. Owing to the peculiar static requirements, it was necessary to ensure horizontal continuity of the reinforcing steel between concreted panels of the diaphragm wall and an innovative technique was developed to achieve this. A similarly sophisticated geometrical technique was used to check the verticality of the diaphragm wall excavation.

An innovative feature of the piling

operations was the under-reaming tool used—claimed to be the first to feature hydraulic operation and in-cab real time readout of depth, progress and diameter. The single or double under-reams it produces were checked for shape by ultrasonic profiler.

Sonic logging was also used to check the homogeneity of the concrete used in all the deep foundation works. Embedded reference potential gauges were used to predict the corrosion of the steel, and embedded anode ladders were used to monitor the advance of chloride penetration into the deep concrete. All underground concrete was electrically connected ready for the application of impressed current cathode protection when corrosion monitoring indicates that it is necessary.

Conclusion

The Bibliotheca Alexandrina is both a link with the past and an opening into the future. Egyptian engineers played key roles in designing and implementing the project.

For Egyptians, the completion of the Bibliotheca represents much more than the establishment of a new library and centre of learning. The People's Assembly of Egypt has enacted a law that declares the library is attached to the Office of The President of the Republic. As such, the Egyptian parliament has decreed that the Bibliotheca will be administered as an international institution for the benefit and learning of the whole world, not just Egypt.

The author believes that the Alexandria Library will be considered as one of the structural wonders of the early years of the twenty-first century, housing the foremost centre of learning in the eastern Mediterranean, just as its predecessor did in antiquity.

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