Precast Concrete and Applications

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Abstract

The profitsachieved from the acceptance of precast concrete elements in civil engineering and building construction are famous. Methods of elements production in projects and on the construction site are studiedfrom the view of the skilled technologist and described, with reference tocompanies of throughput and accomplishment of quality. Equipment of work and facilities aredescribed as design of mould and erection, location of reinforcement, process of casting,techniquesof treatment,emphasis of quality control, and solving problems of production.Fabrication is observed in consideration ofprestressed and normally reinforced membersincluding: members offrame in building, cladding, floor and wall units, and girders of bridges andsegments of tunnel components, box culverts, retaining structures, piles, and elementsused as a defence against sea waves, sleepers of railway.While a concrete skilled workers working within the precast concrete manufacturing should work accurately, encasement is mainlytargeted at those who, working in other parts of the industry of construction, needinformation of the subject.

Key words

Precast, Concrete, Materials, Moulds, Applications.

١. Introduction

١.١ Objective

The objectives ofthis report can be summarized in the following points:

١. Studying a historical background of using and manufacturing of precast concrete.
٢. Studying materials used in producing precast elements.
٣. Explaining several applications of precast concrete in many projects in civil engineering.

١.٢ Historical background

Constructers in Ancient Roman used concrete and thencasted the material into moulds to construct their complicated network of channels,tunnels, boxculverts. Recent uses for precast manufacturing include a variability ofstructuraland architecturalapplications includingentire structural systemsor separate parts of the structure.

In the new world,buildings with precast panel were developed and first used in England,Liverpool in ١٩٠٥. The procedure was developed by city engineer “John Alexander Brodie”, a scientist who also developed the idea of the net of the football goal. The tram barns at “Walton in Liverpool”started in ١٩٠٦. The concept was not taken up broadly in Britain. However, it was acceptedaround all the world, mainly in Scandinavia and Eastern Europe.

In the US, precast concrete has developed as two sub-as two sub-manufacture, each characterized by a major organization. The “National Precast Concrete Association” (NPCA)signifies primarily the industryproduction ofprecast concrete that focuses on underground,utility and other non-prestressed products. The industry that produces structuralprecast concrete focuses on elements with prestressed concrete and on other elements of precast concrete that used in structures above ground such as buildings,

structures of parking, and bridges. This industry is represented mainly by of the Precast/Prestressed Concrete Institute(PCI).[١]

١.٣ Definition of precast concrete

Precast concrete is elements which is cast in afactory for use elsewhere and is a movablematerial. The main part of producingprecast elements is carried out in the works of professionalcontractorswhile in some cases, due to geographical and economic factors, some part ofproduct or large number of the elements are cast on or nearby the site of construction.Themanufacture andpoint of use distance varies extremely, for example distances as tiny as several metres at a field of project where the size of the elementsblock transport from adecided works or where a standby bridge is castbeside to an existing bridge which is inrenovation and is then lifted into location.Much of the productions of professionaldealers is imparted from more than ١٠٠ kilometres in theUK and there are cases where productions have been transported hundreds and eventhousands of miles when sent from the source country.While this study focuses on application of structural and non-structural precast concretemembers, with special sign to members produced in a contractor's industry, themethods and principles of producing at site are the same.The commercial contractor's factory normally includingservices for industrialization arange of production of comparable nature according to the company's specialty, elements of frame,cladding, bridge girdersand etc. The apparatus is thus frequently highly automatic includinghigh-speed batching and spreading of concrete, delivery of concentrated means of mechanicaltreatment and developedfield for quicker curing of produced elements.Naturally, production facilities of the site take the method of unit's production devoted to aspecific production, elements of bridge and piers, piles, segments of tunnel etc., perhapspayingsome of the site services such as the concrete production batching plant and sitecranage for handling product. Production in both circumstancesgradually depends uponoutside source of key items likesteel reinforcement, moulds and in some situation supplying of concretefrom a contractor of readymixed concrete.Wherever the manufacturing is carried out, the basic

management skills, supervisingand the operators employed are basicallythe same. Discipline differences betweenprecasting and cast in placeconcrete work rise due to the repetitive nature of ample of precastconcrete and the chances in producingprecast for automation and controlling bothof quantity and quality. [٢]

٢. Materials and Moulds

Thepurpose of this section is to inform the reader with all the preliminaryvariables. The relateddepiction will then be completelyexplained beforeone proceeds to put these variables into a procedure, in order to produce aproduction ofprecast concrete.

٢.١ Materials

The most often used material construction is concrete and can be considerable ansynthetic stone. In its basic design, it contains the main selected cement, waterand aggregate. State-of-the-artgrades of concrete are quintuple systems that also containadmixtures and additives. These componentsconfirmagreement with detailed requirementssuch as workability of concrete and the hardened concrete characteristics.[٣]

٢.١.١ Cement

The standard cement description must constantly include thegrade of cement, the standard of reference, the shorteneddescription of the cement grade, the strength classand, any special characteristicsif appropriate, for example“Portland cementDIN ١١٦٤ CEM I ٤٢,٥ R-HS”.

The setting behaviour,heat of hydration, volume stability,density and bulk density,colour, and particle fineness are other important properties of cement that must be known.[٣]

٢.١.٢ Aggregate

Granular material to be used in the constructionindustry for precast concrete is called aggregate. Aggregates can be illustrious with respect to their source, particle size,bulk density.

Aggregates are also classified according to their ranges of particle size (or productsizes). Size ranges are specifiedrelated to defined sets of basic screens or sets ofbasic and additional screens.

Some other limits are useful to classify aggregates in the following specifications: Particle composition (particle size distribution indicated by undersizes).[٣]

- Sill deviations from the composition of the typical particle.
- Ratio of fines.
- Resistance against freezing and thawing.
- Resistance againstmagnesium sulphate.
- Lightweight organic pollutionratio.
- Flakiness index.
- Particle shape index.
- Content of acid-soluble sulphate.
- Content of mussel shell in coarse aggregates.

٢.١.٣ **Concrete admixtures**

Admixtures in concrete are finely sparse materials that are used in concrete to reachor recover certain property. “DIN EN ٢٠٦-١:٢٠٠١-٠٧differentiates twotypes of inorganic admixtures:

١. Admixtures with inert property, such as powders of rock in according to “DINEN ١٢٦٢٠:٢٠٠٨-٠٧ or colors in according to “DIN EN١٢٨٧٨:٢٠٠٦-٠٥.
٢. Latent hydraulic or pozzolanic admixtures, such as trass in accordance with“DIN ٥١٠٤٣:١٩٧٩-٠٨, fl y ash accordance with “DIN EN٤٥٠-١: ٢٠٠٨-٠٥” or silica fume accordance with “DIN EN ١٣٢٦٣-١:٢٠٠٩-٠٧”.[٣]

٢.١.٤ Concrete additives

Additives in concrete are powders or liquids that are addedin small quantities to the concrete during theprocess of mixing. They adjust the physical and chemical properties oftheconcrete in the fresh and/or hardened state. In the past few years in specific, many novel,more progressive additives have been launched. Without additives, it would have been impossibleto improve easily compactable concrete (ECC) and self-consolidating concrete (SCC), but also high-performance and ultra-high performance concrete (UHPC).[٣]

٢.١.٥ Mixing water

According to "DIN EN ١٠٠٨:٢٠٠٢-١٠", the following types of mixing water are acceptablefor precast concrete production:

- Drinking water.
- Groundwater.
- Natural surface water.
- Industrial water.
- Remaining water from recycling plants in production of concrete.
- Brackish water or seawater (only for non-reinforced concrete)

The water used for precast concrete must be tested for appropriateness, (tests not required for drinking water).During the mixing water tests, not only the initialtesting requirements, but alsodefined setting time, chemical specifications and compressivestrength limits must be abide to.[٣]

٢.٢ Moulds

Moulds are generally means that:

- Concrete is cast to have a desired shape till it is so strong to be demoulded, or
- Concrete is put in moulds on a machine and holds that shape on almosttime of demoulding, or
- Concrete is formeddirectly after casting using an extra or secondary mould acting on before un-moulded planes.

In the part that comes outlined of mouldingmaterials types are available and how they should be designated. According toeconomic andenvironmental reasons one might be required to a second or third choice, andthis is suitable provided that the persons accountable for this choiceestimate theuse limitations.

Nevertheless all other reasons, the one requirement that all techniques in mouldingand moulds have in public are dimensions. Whether these becritical for constructional, structural and architectural causes is a matterthat causes quite a lot of case. It is imperative that one appreciatesthe reasons for dimensions and what variations are allowable whenjoining the two fields of manufacturing and installation.

Openable mould parts should fit snugly together, if not leakage of cement paste will occur with next risk of concrete flashings andhoneycombing. Sealant tapes and seals that can be compressed are often perfect solutions for leakageproblems. Sealant tapes are usually adhesive PVC tapes with ١٠–٢٥ mmwidth which may be fixed along the joint. The compressible seals areadhesive-backed expandablesmooth plastics tape that may be put insidethe joint at corners and anywhere needed.[١]

٢.٢.١ Steel moulds

Steel moulds(as shown in Fig.١) are used in almost all largeconcrete precast production processes, whethervibrated wet-castlabour-intensiveor machine-intensive large-size production. Clearly the strength andresistance against abrasion of steel makes it the best selection. However, the case is not thathow steel resists to abrasion, it does wear with use and a time comeswhen either renovating or changing becomes essential.[١]

Fig. ١Steel mould made by Hendriks Precon Co. (Netherlands)

٢.٢.٢ Wooden moulds

Timber is the most usablematerialsfor moulding as it is moderately cheapcompared to other materials and is easy to use and shape (as shown in Fig.٢). It is also existing in forms likechipboard and plywood which haveadvantages and disadvantages related to ordinary timber. The twomajor types of wood obtainable are hardwood and softwood. Then, to get a large number of uses of a mould withstabiledimensionit must to use hardwood. Soft woods like Western Hemlock, Douglas Fir and European Redwood. Hard woods such as African Mahongant, Afromosia and Sapele.

The lifetime of a mould related to many factors, the mostsignificant being the used paint to protect the wood. Usuallythe number of uses will vary between ٢٠ and ١٠٠. Nevertheless, timber has the benefit that it can be recycled and re-used again so that economicalcorrectionof measurements can be taken when the mould changed in dimension due to large number of use.

When a timber mould is taken out of use and kept for another use, it should be stored in dry place and in such a way thatdeformation due to dead and/or live load is prevented. All sides of the wooden mouldshould be handled with a thin film of mould release agent to help maintainthe timber. [١]

Fig. ٢Wooden mould made by Invictamoulds Co. (England)

٢.٢.٣ Plastics moulds and linings

Whencomplicated shapes and architectural designcladdings requires these types of moulds and mould linings come into their own (Fig.٣). Theycan be divided in two basic groups of plastics:

١. Thermoset plastics such asglass fibre reinforced polyester resin(GRP), glass fibrereinforced epoxide resin (GRE).
٢. Thermoplastics such as“polyethylene, polystyrene, polyvinyl chloride” (PVC)

The first type are appropriate for such elements as coffered floor elements,architectural precast concrete, garage and house panels, flowerpot pot units, andhave a lifetime of٢٠٠–١٠٠٠ uses when correctly constructed and used.

Second typeof moulds are appropriate as mould linings only, mostly becausethey made in the shape of sheet and would deform if not braced.They can also beformed by vacuum system to give the desired architectural shapes and size by heatingthe plastic sheet over a vacuum griddle with the suitable shape and applying thevacuum in the soft state of the plastics. The lifetime of second type moulds is ١٠–٥٠ uses that depends on the aggregate exhaustion, vibration.[١]

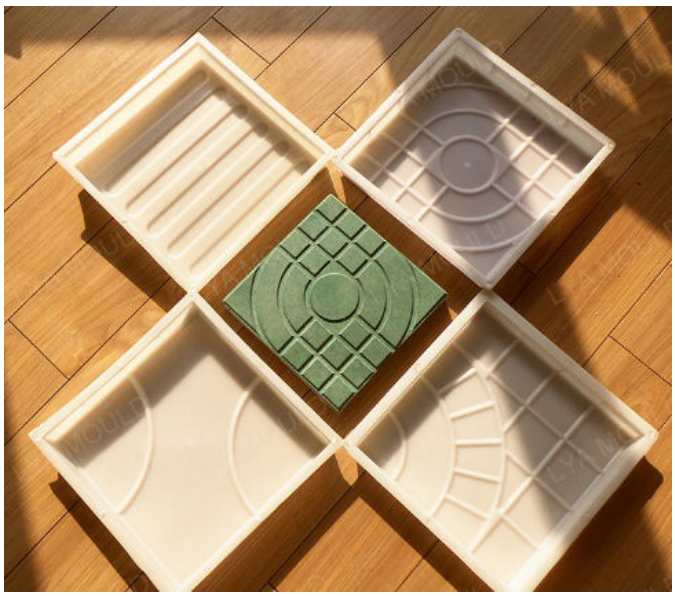

Fig. ٣Plastic mould made by (TYA) company (China)

٢.٢.٤ Aluminum moulds

The most use of Aluminum mouldsare in the manufacturing of roofing tile where they procedure thepallet for the extruded mortar ribbon. The lifetime of this type of mould is many thousandsof uses in tile producingprocess. In the manufacturing of other elements, such aspaving units, wallpanels,attention should be applied in two respects:

(١) Before the mould is put into production the aluminum should be anodised or a couple of dummy casts runoff to form an oxide coating.

(٢) Reinforcement should be far from the mould by required cover otherwise there is thedanger of galvanic action causing formation of bubble on the mould andon the reinforcement, and causing the lossofbond and appearance, respectively.A little potassium chromate solution (٠٠٠٠١% w/w cement)can be added to the mix where this is cannot be avoided and the cement conatins ١٠ ppm of chromiumor less.

Aluminum has thermal expansion propertytwice the of steel orconcrete moulds and should avoid to use aluminum moulds as a construction mould material where the size of concrete is such that shrinkage while setting and cooling ofthe warm or hot

concrete can cause extra stress in the concrete and cause cracking (as shown in Fig.٤) .[١]

Fig. ٤Aluminum mould made by (ADTO Industrial Group) company in China

٢.٢.٥ Concrete moulds

These are not a common mould as they are heavy and hard touse; however, (concrete mould has a tolerance level of use in production industry more than any other types of moulds. There isusually about millimeters of tolerance for other types ofmould but for concrete moulds there is a fractions of such a unit. Suchallowable change in dimension would be in order for tunnel lining units of circular elementswith rhomboid mating faces where, say, completing a ring with eight elements of such units, with the final unit fixed in its location acting as the keyunit.The concrete mixture used in the manufacture of mould is best made of a“flint gravel or volcanic rock coarse aggregate and a natural well-gradedsand fines with a cement content of ٣٥٠–٤٠٠ kg/m^{٣} and an effectivewater cement ratio of ٠٠٤٥ maximum”. Accuracy in manufacturing the mouldis significant but for a tolerance units like thisit is normal tomake the mould a bitlarger and grind it to a template finish.Concrete moulds, with appropriate care and handling can be used manythousands of times.[١]

٣. Application of precast concrete

٣.١ Structural Application

٣.١.١ Precast concrete for building frame

٣.١.١.١Columns

Precast columns (as shown in Fig.٥) are exist in a range ofsizes, shapes and finishing, can be square or circular and are designed to combine with any addedfittings or features. In single storey column's length are commonly ٢.٥m - ٤m high. Beams bear directly on top of columns with a suitable connection between beam and column. Corbels are used for multi storey columns or other connections at locations to connect with the beams at middle levels. Projected rebar can be fixed for connecting in to in situ floors. Cast in base plates, dowel tubes or projecting bars are options for foundation connections. [٤]

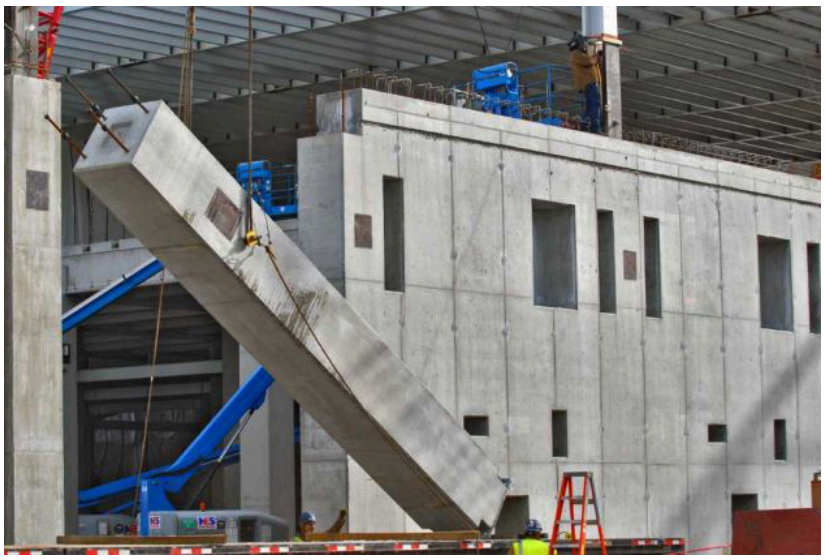

Fig. ٥Precast column by (EYOTA) company.

٣.١.١.٢ Beam

In cast in place system concrete slabs and beams require complicated formwork during construction to bear the weight of fresh concrete and moulds. These forms shall be in place for approximately ١٠ days or more according to the slab dimensions, so that concrete gains required strength and carry the self and imposed load if any. This formwork needs time to erect and include material stocking and also large

labour needed. The project should be sequenced as the beams or slabs cannot be completed until their supports or columns are cast.To conquer these insufficiency, the use of precast beams has developed. Beams or slabs are cast as per convenience in advance. These precast beams are located in placeusing cranes. (Fig.٦ shows types of precast beams and Fig.٧ shows a precast concrete beam).[٤]

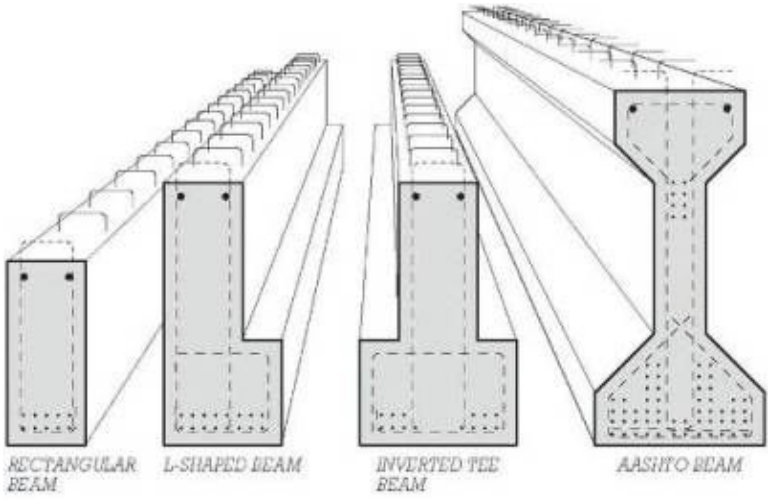

Fig. ٦types of precast concrete beams

Fig. ٧Tapered precast concrete beam

٣.١.١.٣ Hollow core precast Slab

A voided slab also known as a hollow core slab , hollow core plank or simply a concrete plank is a precastconcrete slab of prestressed concretenormally used in the floorconstruction in multi-story structural buildings. Where the emphasis of home construction has been on precast concrete the precast concrete slab has been particularlycommon in these countries, such as“Northern Europe and former socialist

countries of Eastern Europe". Using precast concrete system is popularity related to low-seismic zones andconstructions economically because assembling building elements are faster, lower self-weightand less materials used (as shown in Fig.٨). [٤]

Fig. ٨Hollow core precast concrete slab

٣.١.١.٤ Precast concrete walls

Precast wall panels are only used for exterior and interior walls. Compressed in concrete and stone, creating a solid but movable wall or face. By producing precast concrete in a required environment (typically denoted to as a precast concrete plant), the precast concrete is afforded the chance to properly treated and be closely supervised by plant staffs. Production of precast concrete can completed on ground level, which helps with safety while completing a project. There is great supervision over the quality of material and specialist techniques in a precast plant when compared to a construction site. The moulds used in a precast concrete plant can be reused hundreds to thousands of times in production of elements before they have to be changed, indeed making it cheaper than casting in-situ when studying at the cost per unit of formwork (Fig.٩, Fig.١٠ and Fig.١١ shows fence, building precast concrete walls and precast retaining walls respectively). [٥]

Fig. ٩Precast concrete Fence

Fig. ١٠Precast concrete building wall

Fig. ١١Precast concrete retaining wall

٣.١.٢ Precast concrete for Bridges

٣.١.٢.١ Solid Deck Bridge

Density of traffic on and around most bridges has increased dramaticallywith urban expansion. One very substantial standard in selecting a deck rehabilitation system is that it must minimizeconfusion with local traffic. Fastconstruction by using segmental full depth,precast deck elements is mainlyappropriate in meeting such a desired requirement (as shown in Fig.١٢). [٦]

Fig. ١٢Precast Solid Deck Bridge made by (Old Castle) comp.

٣.١.٢.٢ Girder Bridge

A girder bridge is a type ofbridge that uses girders as the element of supporting the deck. A bridge generally consists of three main parts: the abutments and piers (foundation), the truss,girder, or arch(superstructure), and the deck. A girder bridge is the most generally used and built bridge in the world. Its basic design, is the most easy form, can be compared to a log ranging shape one side to the other across a river or creek. (Fig.١٣ shows Girder Bridge under construction and Fig.١٤ shows precast concrete girders). [٦]

Fig. ١٣Girder Bridge under construction

Fig. ١٤precast concrete girders

٣.١.٢.٣ Box Girder Bridge

When the main beamsincludegirders in the shape of a hollow box, a girder bridge is called box Girder Bridge. The box girder normally involves either prestressed concrete, structural steel, or a composite of both steel and reinforced concrete. The boxcross-sectionshape is typically rectangularshape or trapezoidal. Box girder bridges are generally used for expresswayflyovers and for new elevated structures of light rail transportation. Cable-stayed bridges are another application of box girders.(Fig. ١٥ shows box girder bridge under construction and Fig.١٦ shows the steps of box girder development) [٦]

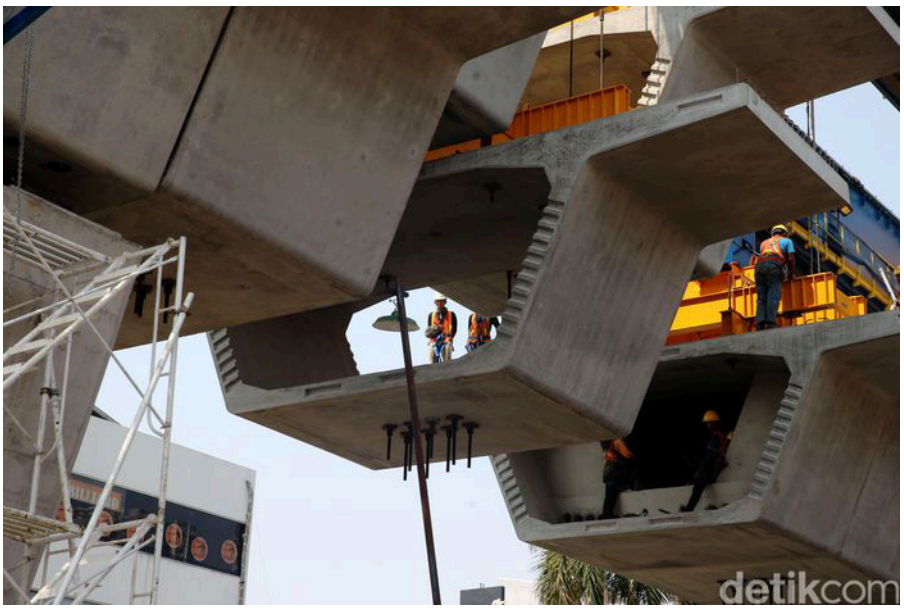

Fig. ١٥Box Girder Bridge in Jakarta under construction

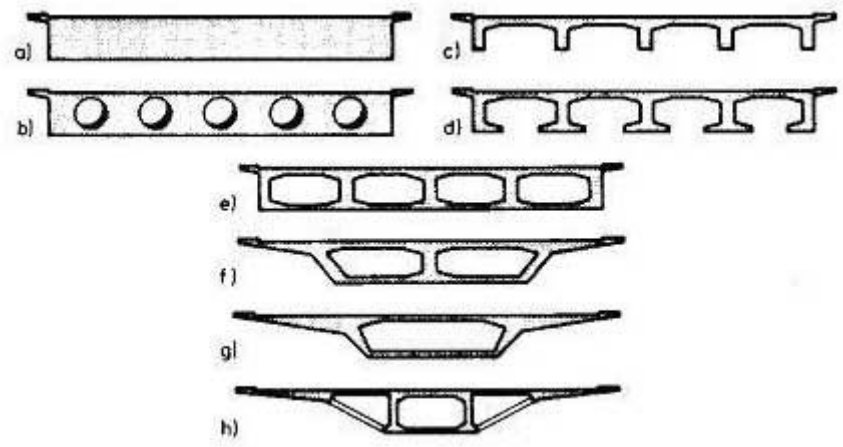

Fig. ١٦Steps of development of box girder

٣.١.٢.٤ Box culvert precast bridge

Many systems are exist for consideration before substituting a bridge. Onealternateof bridge systems to be used is box culverts in precast form (as shown in Fig.١٧ and Fig.١٨). Wereproposedwide range of sizes and shapes to fit detailed requirements of site conditions. When correctlyfitted, a box culvert bridge replacement can offer maintenance-free service for many years. There are concrete box culvertunder use today that are ١٠٠ years old, and many of these box culverts don't need anymaintenance budget annually.[٦]

Fig. ١٧Precast box Culvert Bridge

Fig. ١٨Precast box Culvert under construction

٣.١.٢.٥ Tunnel Segment precast concrete

Covering inside of tunnels can be made in several methods, one of these methods is by using precast concrete segments casted in a concrete plant then transported to the site for erecting in most cases ٧ or ٨ segments make a complete circle to cover the entire tunnel (as shown in Fig.١٩ and Fig ٢٠).

Fig. 19*Precast Concrete tunnel segments ready for use*

Fig. ٢٠Tunnel covered using Precast Concrete segments

٣.٢ Non-Structural Application

٣.٢.١ Precast Concrete Feed Troughs

Another application of precast concrete is used in farms for many reasons, one of them is eating and drinking troughs (as shown in Fig.٢١) which have a lot of benefits such as:

- Reducing waste as the animals have entree to the feed at all times.
- Animal feed intake increases.
- Saving workmanship as no need for pushing feed up.
- Keeps passageway clear and clean.
- Easy quick and installation.

Fig. 21*Precast concrete trough in a farm made by (Spillane Precast concrete Co.) in Ireland*

٣.٢.٢ Precast concrete pipes

Manufacturing reinforced concrete pipes made by using two identified production processes: roller suspension and automatic vertical casting using high durability high strength concrete. Both these methods are used worldwide and are approved to be perfect for manufacturing concrete pipes.

Controlled conditions is necessary for manufacturing processes using advanced equipment and technology. These procedures provide flexibility for the

manufacturing of tailormade wall with various thicknesses for special strength and load requirements.

If corrosion problems are expected, there are several methods of extending the life of the concrete pipe. The replacement of the siliceous aggregates with calcareous aggregates gives a good result in the prolonged life of the concrete pipe as shown in Fig. ٢٢). [٦]

Fig. ٢٢precast concrete pipe

٣.٢.٣ Water breaker precast concrete

Development ofharbour on open or partly protectedbeachesusuallyneeds the construction of awater breakers or breakwaters, to offersuitableshelter from sea wave effects to permit effective operation of the harbour. All shapes and sizes available and made of precast concrete (as shown in Fig. ٢٣ and Fig. ٢٤). [٧]

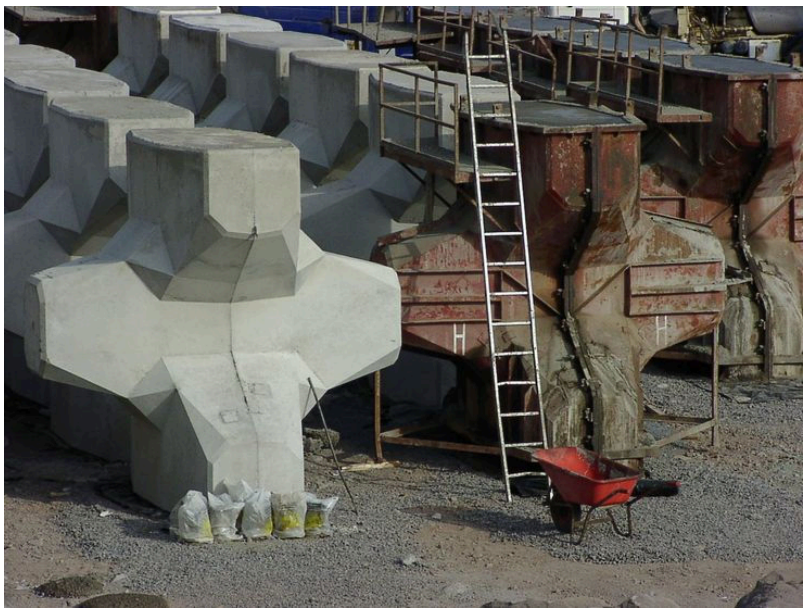

Fig. ٢٣precast concrete water breaker

Fig. ٢٤Precast concrete Water breaker (Tetrapods type)

٣.٢.٤ Precast Concrete Barriers

Precast concrete barriers are used to reduce the danger of an out-of-control automobile crossing the median and hitting with opposite traffic or roadway labors (as shown in Fig.٢٥). Reduce the risk of a vehicle turn back into the traffic stream after hitting with the barrier.Slow the errant vehicle within acceptable limits.Guiding traffic in anaccepted manner.Used asa security against undesirable vehicular

movement and terrorist events aroundutility facilities, government buildings, historical landmarks and airports. [٧]

Fig. ٢٥Precast concrete barriers

٣.٢.٥ Precast Concrete Curbstone

Curbs may have several functions. By outlining the edge of the roads, they detach the road from the roadside and discourage drivers from driving or parking on sidewalks and lawns. They also offer structural support to the asphalt edge. Curbs can be used to channel extra water from rain or melted snow and ice into storm inlets.There is also avisual aspect, in that curbs look official. They are usuallyused in urban and suburban zones, and are infrequently found in rural zonesexcluding certain drainage conditions (such as mountains or culverts) make them essential (Fig. ٢٦ shows types of precast concrete curbs). [٨]

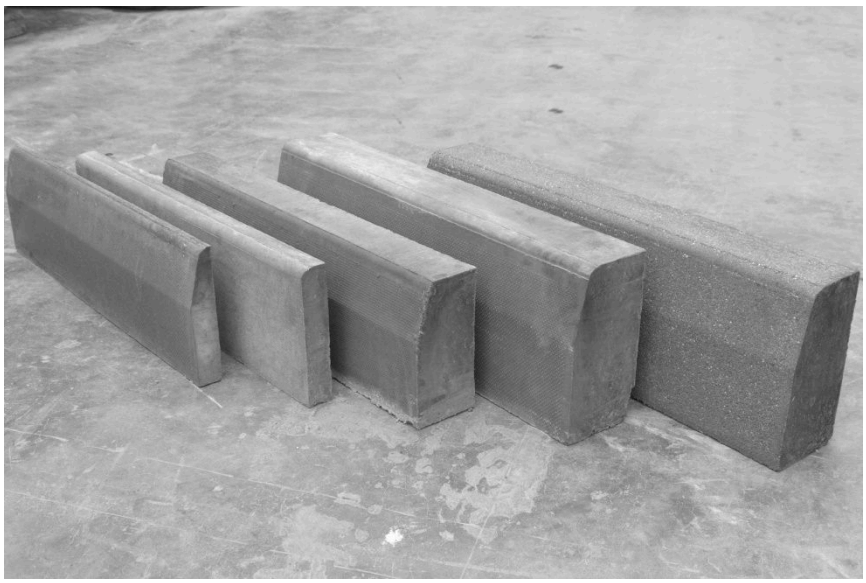

Fig. ٢٦*Precast concrete curb stone*

٣.٢.٦ Trapezoidal Channels

Precast concrete trapezoidal channels are used as a faster, economical, offsite substitute to slipform (as shown in Fig.٢٧).[٨]

Fig. ٢٧Precast concrete Trapezoidal Channel

٤. Conclusions

Finally precast concrete has a wide range of use and application around the world including structural and non-structural structures, it can be concluded that:

- The use of precast concrete and prestressed concrete isestimated to have nearly doubled in the last many years.
- The use of precast concrete construction cansignificantly reduce the amount of construction wastegenerated on construction sites.
- Reduction ofopposing environmental impact on sites.
- Improve quality control of concreting work.
- Reduce the number of site workmanship.
- Increase worker safety.
- Other obstruction to precasting andpreassembly are increased transportationproblems, more inflexibility, and more advanced insurance requirements.

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