Industrialised production of precast and prestressed concrete products in north America

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The use of precast, both reinforced and prestressed, building components is very widespread in many developed countries. With a view to encouraging their acceptance and use in India, the author briefly features their production processes in various factories studied during a recent visit abroad.

Technological advancement in one industry will reflect in every other industry and changes will take place accordingly. This is very much true in the case of construction industry as well. The developments in steel industry affected various kinds of alloy steels production, which in combination with developments in material handling techniques brought drastic changes in the automobile industry, improving quality and quantity at an economical cost. Similarly, the developments in reinforced concrete and prestressed concrete have brought about numerous changes in the construction industry, enabling the manufacture of precast concrete products for building construction and various other construction industries. This has further led to the development of mechanised production methods and factory oriented production of precast concrete products. In a factory the product is divided into a number of components and the necessary connections or joining hardware are inserted during casting before the components are assembled at the site. This enables the production of components inside the factory to the required shape, finish and quality resulting in the uniform quality and savings in labour, materials, etc.

The production facilities in a precast concrete plant are generally designed to be completely flexible to produce a range of products to cater to the rapidly growing demands for residential, commercial, industrial and institutional structures, in addition to the requirements of rail, highway, marine and agriculture industries. This paper presents a brief review of current methods, being practiced in north America for the manufacture of precast and prestressed concrete products.

Organisational set up

Most major cities in this continent have two or three precast concrete plants to cater to the demands of local construction industry. Each plant is normally headed by a general manager, who is responsible for the overall activities of the plant. A team of managers from various departments such as engineering, production, erection, sales and accounts will assist him in the running of plant. Engineering department prepares the necessary designs drawings, and estimates of each project. Production department is responsible for the production of precast components in the plant. It in turn consists of various branches headed by a plant superintendent who leads a team of formen directly responsible for preparing moulds, reinforcement, concrete and casting. Erection department handles the finished products in the storage yard, transports the products to the construction site and erects the units. Sales department prepares the nccessary advertisements, conducts sales and deals with public relations. Accounts department handles the necessary accounts of the factory, it also prepares the day to day profit and loss data sheets of each department with the help of a computer, based on previously prepared estimates of each product. Before taking up a project each department is consulted and the necessary rough estimates are prepared based on previous experience. The final drawings and actual estimates are prepared after the project is allotted. Besides the above departments, every factory employes a quality control inspector who is directly responsible to the general manager and maintains a daily record of the test results obtained. Some plants employ an independent consultancy agency to maintain the quality control within the plant.

Precast manufacturer works with the developer, owner or architect to preare a tentative floor plan and within a matter of weeks a preliminary superstructure price for the required building can be obtained permitting the general contractor to take a decision on the type of construction to adopt, with little time or money spent.

Production methods

The essential feature of a precast concrete plant is to utilise an industrial production process such that an optimum use of equipment, with better utilisation of labour employed is made. The various processes used in a precast concrete plant can be grouped as under:

Long-line precasting methods: Long-line precasting methods are generally employed for the production of prestressed precast concrete products such as, hollow-core units for roofing and walling, concrete piles, bridge girders, single-T, double-T units, railway sleepers,

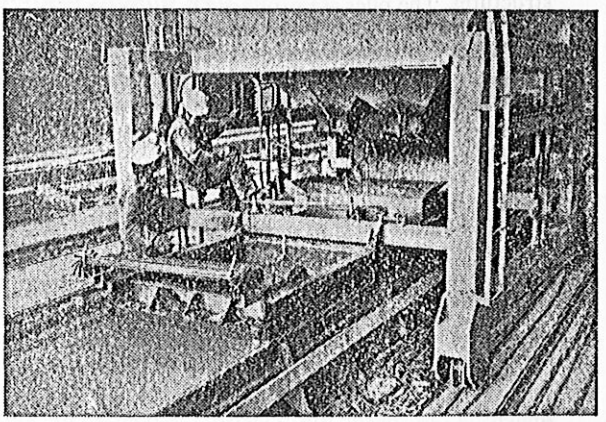

Fig 1 Hollow core unit casting machine

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concrete poles, etc. A long bed of 100 to 200m length is laid inside or outside the shed. Fixed anchorages are provided at both ends of the bed to apply pre-tension to high-strength steel strands, or wires. An electric overhead travelling crane is used to handle the moulds, materials and finished products. Steam lines, including steam distribution system is laid along the bed to cure the products after casting. These are normally covered temporarily. The moulds are placed on the bed in a line and prestressing strands are fixed with the help of girders and steel plates provided at the ends of the beds for anchoring. Required pre-tension is applied with the help of hydraulic jacks operated by electric-driven pumps. Some of the products which can be produced using long-line casting methods are detailed below.

Hollow core concrete units—Precast, prestressed hollow core concrete unit is very popular in north America as a roofing and walling unit in various types of buildings. The basic unit is of 1200mm or 2400mm width, with thickness varying from 150 to 300mm. The unit can cover a maximum span of 12m. These are being produced on long-line precasting beds of about 100m length or more. The units are cast on a steel pallet in a single or multiple runs of the hollow core unit casting machine, *Fig* 1. They are cured by steam or hot water, or hot oil, with the heat circulating pipes placed below the casting beds. The units are normally cut to the required lengths and widths with diamond saw cutters before removing to the storage yard. There are several highly mechanised processes available for producing these units.

Single-T and double-T—These are prestressed, single or double-T shaped units used for floors and roofs. T's are generally large members for spans of 15m to 30m. These are mostly used for long span structures such as industrial and commercial buildings. These are produced on a long-line casting beds using permanent steel moulds, while the concrete is poured with drop bottom buckets using overhead cranes or other equipment. The concrete is consolidated by high-frequency shutter vibrators and needle vibrators. These units are also used as wall units by changing the position of prestressed strands and by applying architectural finishes to the exposed surfaces. Almost all types of prestressed, precast concrete bridge girders to be used in overpass structures, stream crossings and long span structures over major rivers are produced in precast plants. The units are produced on long line beds in exactly the same way as single-T and double-T units.

Precast, prestressed concrete piles—Precast, prestressed concrete piles are used in foundations for various structures. The piles are produced in different shapes such as circular, hexagonal, octogonal cross-sections, solid or hollow. These units are produced upto 25-m length pieces on a long-line bed using steel moulds. The diameter of the piles varies from 350 to 900mm. It requires special care for casting the hollow core piles. To avoid honey-combing in the concrete, very stiff concrete is used for casting, this requires the concrete to be placed in moulds with a special bucket fitted with a vibrator carried by the overhead crane. For making hollow piles, a vibrating mandrel is inserted into the mould before starting the casting which continuously moves during the casting from one end to the other. The mandrel consists of a steel pipe of required diameter of core with pneumatic vibrators fitted inside on the diaphragm plates to vibrate the concrete and to make the core inside the pile.

Prestressed concrete railway sleepers—Sleepers in north America are of prestressed, monoblock type, about 2.8m long and each has several prestressing wires. Malleable iron shoulders are embedded in them to accommodate pandrel fastenings. The rated capacities of the plants varies upto 1300 sleepers per day. The sleepers are cast bottom side up, provision is made for embedding inserts for the clips into the concrete during manufacturing process.

The manufacturing process starts with fixing of pre-stressing wires in their position in long-line moulds. Bulkheads are placed across each mould to separate the sleepers after casting and curing. The wires will be stretched by hydraulic jacks and anchored at the ends. Concrete for the sleepers is supplied by a mobile placer, that places and vibrates the concrete into the forms as it moves along the bed. After completing the casting the moulds are covered by a canvas sheet. Heated oil or steam is circulated in pipes placed under bed for accelerated curing. When the curing is completed the bulkheads are removed and the prestressing wires are released from the anchorages. They are then sawn apart between the moulds, thereby transferring the stress to the concrete and creating a prestressed condition in each sleeper. The sleepers are then lifted from beds and turned rightside up to be placed on a flat car to be transferred for stock piling or directly to the installation site. Several special equipments for placing concrete, prestressing the wires, removing the sleepers from beds, cleaning moulds, handling and other works have been developed to improve quality and speed of casting the sleepers.

The long line precasting method can also be utilised to various other products such as concrete poles, balcony slabs etc., wherever a uniform cross-section along the length is required. It is generally used for mass production, so the labour acquires special skill, which results in considerable savings in labour cost.

Individual mould casting methods: Individual mould casting methods are generally employed for casting reinforced concrete products, *Fig* 2. It is also used sometimes for casting prestressed concrete products. When used for casting prestressed products, the moulds are designed to take prestressing stress applied to the wires or strands. In this process individual moulds are placed inside the shed and concrete is filled with drop bottom buckets handled by overhead electric cranes or other material handling equipment. Consolidation of concrete is done by high frequency, needle, pneumatic, or electrical vibrators. The units are cured with steam. Finished units are handled by overhead electric cranes or fork lift cranes within and outside the

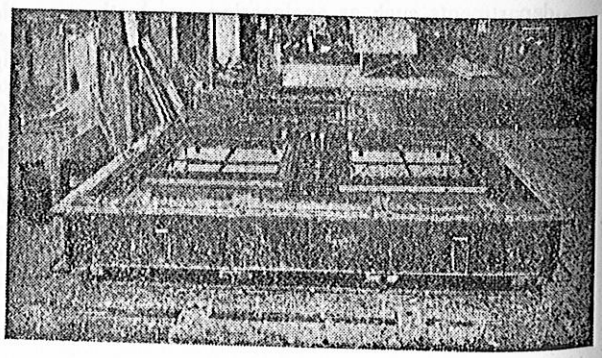

Fig · 2 Mould for casting wall panels

sheds. Columns, beams, load bearing and non-load bearing wall panels, architectural panels, hollow concrete poles, underground vaults, cable ducts etc. can be produced by this method.

Production of some of the above mentioned products using various individual mould processes is explained below.

Tilting mould — Load bearing wall panels are produced on horizontal tilting table moulds. They can be tilted up for stripping the unit after curing to minimise handling stresses. The size of the table varies upto 12m in length and 7m in width. It is fabricated from 5-mm thick steel sheet, stiffened with steel sections underneath. One side of the table is hinged to the ground anchors, and the other side is provided with hooks to lift the table with overhead crane. The table provides an easy access for arranging reinforcement to provide window and door openings, finishing and other operations. The size of the unit and thickness can be changed easily by changing the side forms. This is also used for casting cladding panels, normally using welded wire mesh reinforcement and by providing ribs in the panel. In addition to load bearing panels, other types such as sandwitch panels, etc. are also produced in tilting moulds.

Spun concrete — Prestressed, precast concrete poles are used for electrical transmission lines, telephone supply lines and for lighting poles. These are being produced by individual moulds in spun casting methods. The poles are circular, hollow and tapered in section of lengths upto 20m and diametres upto 450mm. The concrete in the mould is subjected to centrifugal action by rotation. The concrete is consolidated to the shape of the mould with uniform density and thickness.

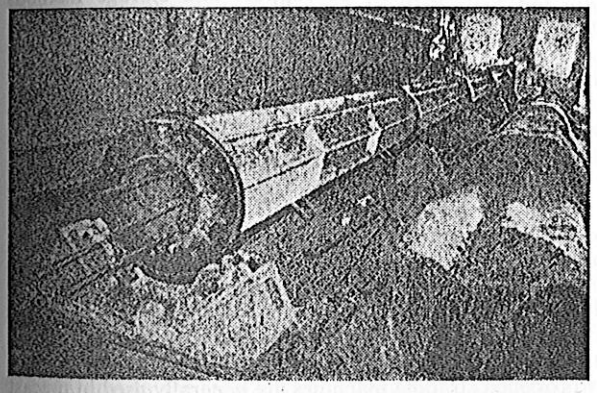

Fig 3 Equipment for casting spun concrete poles

The equipment consists of a steel mould fabricated from steel plates, in two semi-circular sections, stiffened with ribs and flanges. End plates are provided to hold prestressing wires and one end plate is fixed with a clutch housing to engage an electric motor for spinning the mould. Circular rings are welded to the mould to support the mould on rollers for spinning. There are four supporting rollers along the length of the mould to support the mould during spinning, *Fig* 3. The rollers are fixed with ball bearings and they prevent the transverse movement of the mould.

After cleaning and oiling, one-half of semicircular mould fitted with end plates is placed on the supporting rollers. The reinforcement is fixed in its position. Required amount of concrete is placed in the mould and top

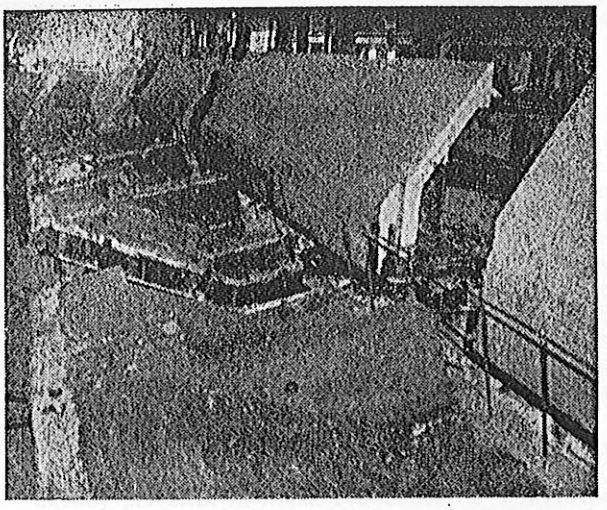

Fig 4 Casting of architectural concrete panels

mould is fitted on and tightened into position with bolts and nuts. The prestressing wires are then pulled and chucked to the end plates. The clutch is then engaged to rotate the mould on its central axis with a variable speed electric motor at predetermined speed for about 15 minutes to finish the casting The mould is then lifted from the rollers and placed under cover for curing.

Architectural products — Architecturally finished concrete elements are normally used for clading or curtain wall application and sometimes used as load bearing wall units. These are produced from individual moulds. The moulds are either of steel or wood depending upon the number of castings required and architectural shape of the units. When the units are produced with coloured surfaces, two different concrete mixes, *i.e.* face mix of about 25mm thick and remaining backup mix of normal concrete is used for economy. Panels of U- or L-shape are cast in two or three stages to achieve uniform thickness of surface concrete by providing cold joints in the units, *Fig* 4.

Individual mould process is also used for producing several other products such as columns, beams, road kerbs, underground vaults, cable ducts, transformer bases etc. The type of mould and material used for making the mould depends upon the number of castings and shape of the products.

Concrete mixing and placing

Concrete mixing and placing assumes a great importance in a modern precast factory. The cement is brought by tankers provided with air blowing pumps, so that the cement storage silos are filled directly from the tankers. Aggregates are normally stored in overhead silos provided over the concrete mixer and these are filled with a horizontal belt conveyor and a vertical bucket elevator. In small plants the aggregates are stored on ground separated with partition walls and these are transported to the mixer by using dumper or a bucket conveyor.

In an automatic batching plant cement, aggregates, water and other materials is controlled from a central control panel. High-speed cyclone type mixers having 2 to 4m^3 capacity, fixed with moisture measuring devices are generally used for efficient mixing of concrete. Mixers are fixed at a height with bottom discharge gates. Concrete is normally carried in drop bottom bucket placed on a buggy.

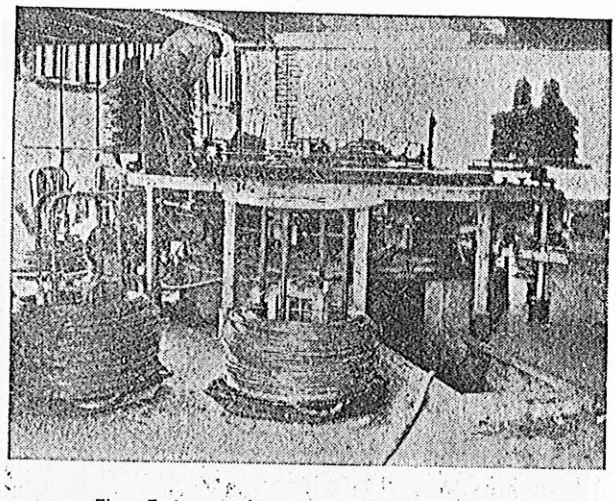

Fig 5 Automatic cage making machine

The bucket is lifted and carried over by overhead cranes for pouring concrete into the moulds. Some factories also use mono-rail bucket conveyors, to move concrete from the concrete mixer to the mould. In some small plants, where the mixing facilities are inadequate the concrete is brought from ready-mix concrete plants in agitator trucks. In open casting yards, the concrete is carried by dumpers, or by drop bottom buckets attached fork lift trucks to fill the moulds.

For compacting the concrete, high-frequency electric, pneumatic or hydraulic vibrators are generally used. For large units such as bridge girders, double-T, etc. high-frequency shutter vibrators are attached to the moulds and portable needle vibrators are used inside the mould. The mobile equipment for casting railway sleepers and hollow core units are fitted with hydraulic or electrical driven vibrators to vibrate the concrete but not the moulds, while travelling along the bed.

Preparation of reinforcement and prestressing

Reinforcement required for the units is prepared in a separate production line provided in the precast plant with equipment required for cutting, bending and welding of steel bars. For reinforced concrete, plain steel bars and deformed or ribbed steel bars are cut and bent according to shop drawings. Automatic straightening and cutting machines are used for straightening the coils in an uninterrupted process. Power driven bar benders are extensively used for bending steel bars in to various shapes.

Different types of welding machines, such as spot welding machines, butt welding machines, welding trasformers are used for welding reinforcement cages etc. Some plants employ complete automatic cage making machines, starting from bending reinforcement bars, shaping, welding, to cutting operation, *Fig* 5. In case of prestressed, precast concrete units the steel wires or strands are tensioned in advance before concrete is cast, *i.e.* pre-tensioned and anchored between fixed abutments installed at each end of the bed, or to the mould itself. The concrete is cast around these tensioned wires. When the concrete has acquired sufficient strength the anchorage of the wires at the abutments is released transmitting the prestressing force to the units. The abutment frame is usually constructed of rolled steel sections, assembled by welding, *Fig* 6. The individual prestressing wires or strands are anchored in a perforated bearing plate with the aid of wedge anchorages.

Pre-tensioning is usually done by special hydraulic jacks, which can hold the wires or strands against abutment and stretch the wires to the required tension.

For transferring the prestressing force to the concrete, stress releasing jacks are used in some cases, to prevent the moulds from sustaining damage due to sudden release.

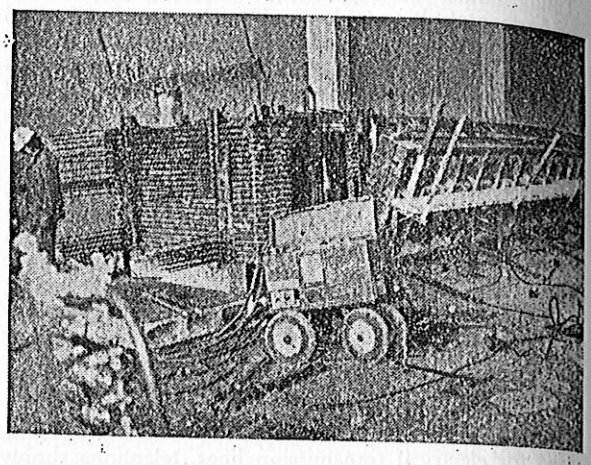

Fig 6 Anchoring and prestressing equipment for long line precasting

Storage, handlings and transportation

Methods of handling and storing of units differ from plant to plant. Location and type of lifting inserts, additional reinforcement to resist lifting and handling stresses, designation of support and storage methods are engineered before production is commenced and handled accordingly. There are no standard methods, the important criteria are safety and protection of the products. Units are stacked separately and supported on strips of wood or battons across the full width of each bearing point, *Figs* 7 and 8. The storage areas are large enough to store the units properly with adequate room for lifting equipment and trucks to manoeuver.

Cranes and lifting machines vary from plant to plant. Many types of equipment are available for lifting and placing. Selection of the equipment depends upon individual choice. Heavy-duty fork-lift trucks, truck cranes, truck-mounted hydraulic cranes, overhead bridge cranes, gantry cranes and rubber-tyred self-propelled straddle machines are generally used in precast

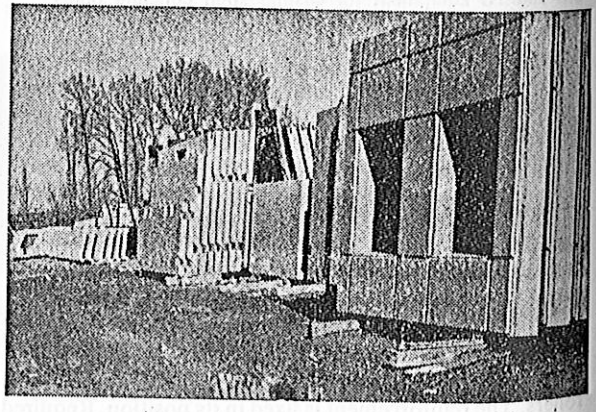

Fig 7 Storage and stacking of precast units

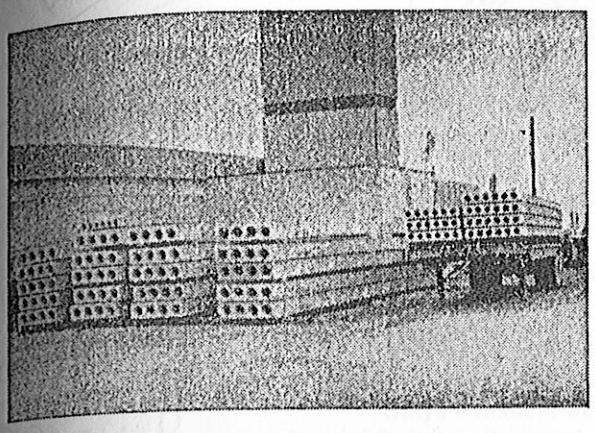

Fig 8 Storage and stacking of precast units

plants for lifting and handling. Handling of units involves removing the unit from the mould or form, transporting to yard or storage, loading and transporting for erection.

Depending on the size, weight and type of unit and place, a number of lifting and handling techniques and various hardware items for attaching the rigging to the concrete are used. Anchoring devices are embedded in the concrete during casting, so that it can be attached to a lifting hardware when required to lift. A simple device frequently used on several prestressed products is to embed a loop of prestressing strand in the concrete leaving the loop exposed for attachment to the crane hook.

Transportation of precast concrete products is a specialised business, which requires special skill and equipment. Normally the manufacturer himself transports the units to the construction sites, but other specialist organisations are also available. Truck, trailer combination for handling heavy products is a common practice, *Fig* 9. Precast units loaded on a truck or carrier will need adequate support and cushioning by blocks and ties to prevent damage. Units are supported on trucks as they were in storage yards with added bracings, so that they remain in this position without shifting or overturning during transportation.

Precast panels are supported on A-frames on the bed of the truck or carrier to hold panels in nearly vertical position, *Fig* 10. Pole trailers are used for transporting very long and heavy units such as single-T's, bridge girders with precast unit serve as pole connection between truck and trailer. Trucks and their loads must conform to the local laws and conditions, especially with long and wide loads. The units are generally delivered to the job site in fit condition for erection.

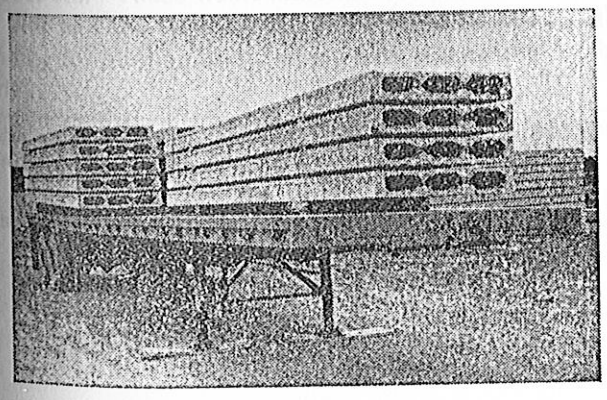

Fig 9 Truck trailer for transporting precast panels

Conclusion

The building construction activity in America and Canada is mainly organised in the private sector. Manufacture of precast concrete products is a well established industry and competitive with other construction methods. There are about 300 precast plants throughout the United States and Canada. Precast, prestressed concrete products are used in building industry and other construction industries such as marine structures, railways, highways, etc. With the present rate of development it is possible to keep an inventory of standard industrialised components for roofing and walling of various buildings and bridge girders, piles, etc.

The manufacture of prestressed concrete railway sleepers, electric poles and various types of beams is already prevalent in India. Production of hollow-core units have also been tried by some parties. It is therefore useful to study the production technologies being practised in north America to further improve upon the quality and bring down the cost of these products in India. Production of prestressed concrete piles can be taken up as there is a large market for this product for multi-storeyed buildings, which are being built at a very fast rate in the big cities of our country.

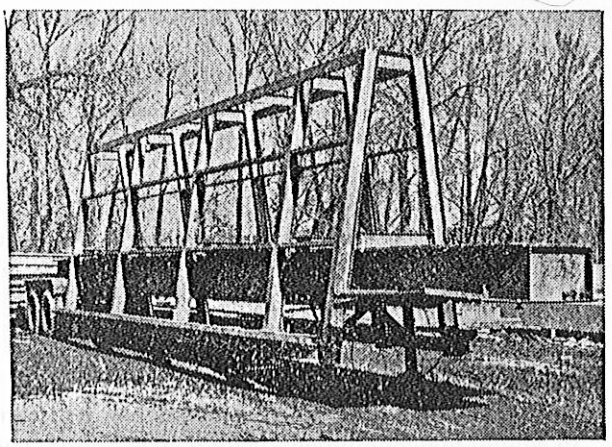

Fig 10 Trailer mounted A-frame for transporting wall panels

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