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THE IDEA OF SUSPENSION ELEMENT AS PROTECTION OF PRECAST COMPONENTS

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Abstract: The Industrial Building System (IBS) technique does bring advantages such as reducing wastage and cost, time and enhance quality. However, regardless of IBS's advantages, it does have some critics, especially when it involves gross error on human interference that lead to unsafe acts. Too many machinery also can cause hazards to workers. These weakness lead to misperception of IBS in construction society, especially when it resulting to product defects. This research is aiming for defect control by minimising material handling and human interference in the storage and transportation of precast components. Thus, a self-loading suspension rack (SLSR) model is proposed to chattered the issues. SLSR shall be created by merging the concept of suspension system with the innovation of automation moving rack. Construction sequences, production storage and delivery process, are therefore important and need to be closely monitored to prevent costly double handling such as rectification work in site progress or re-costing for product returned. A control from the manufacturing phase is significant for overall productivity and performance of the precast plant.

Key words: *Defect; rack; suspension; loading; storage; delivery.*

INTRODUCTION

Precast construction is now becoming a mature method in the construction automation market and can be categorised into four cycles: design, production, storage and transportation, and erection [1]. After the client's requirements are issued, the project design can be developed and passed to the precast plant for fabrication. The precast plant must transport the components to the site for erection based on the project's erection requirements and schedule [2][3][4][5][6]. The precast construction technique does bring advantages such as reducing wastage and cost, time and enhance quality.

Poor material handling leads to occurrence of defect. Major defect in precast concrete system are cracks. Cracks are a major quality control problem, regardless of whether a building component is casted onsite or offsite production. Many researchers have agreed that concrete spall in precast segment were categorized as normal defect to be recorded during the manufacturing and delivery stages [7]. The researcher added that defects such spall and cracks will require a high attention of rectification work. This scenery would take time on completion, the need to pay worker wages on repair work, to find suitable grouting, while in worst situation could lead to product returns. These are generally considered as double material handling.

Estimates suggest that costs for correcting defects may account for up to 6% of the production costs [8]. Factors contribute to cracking during storage would probably cause by interference of human and machine during loading and unloading. Meanwhile, cracks that occur in transportation process might cause by vibration which can be solved by suspension elements. Cracks in storage are considered to be gross error in material handling. In any case, precast components should be stored with careful consideration on protection to ensure components delivered without damage. Thus, to reduce crack effects, minimizing material handling

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in term of workmanship and machineries usage shall be comply together with enhancing the quality protection of the product.

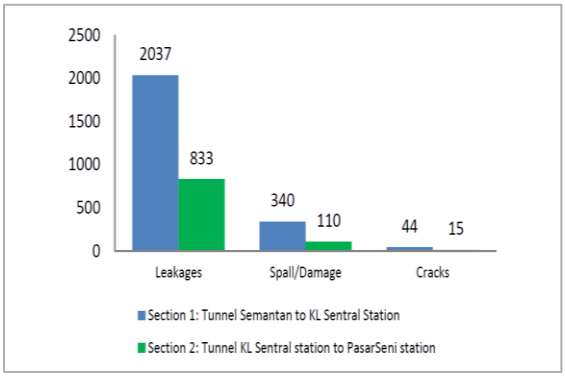
LITERATURE REVIEWS

It is important to make provisions to store the precast components for subsequent delivery process. Casting offsite product enhance monitored quality issue. However, the occurrence of crack can still be found when delivered to site.

2.1 Occurrence of Crack in Precast Concrete

Transport and lifts caused some 10% of the defects detected in the final audits (Figure 11) manifested in cracks in weak sections, and windows and doors in need of adjustment [9]. A survey on product quality has been carried out on case study of Tunnel Segment Klang Valley MRT Project (KVMRT), 2015 via precast steel fiber reinforce concrete (SFRC), and the results came out that 84% of precast product were stacked without protection such as rubber pad, and 12% respondent believes that precast segments was cracks due to uneven thrust load during shoving and 4% respondents say that crack were already occur during casting phase [7]. Risk analysis based on supply chain operation references (SCOR) was conducted, and the result of total risk of priority index (RPI) for defective products during production; product returns from customers; damage when shipping is about 30% of supply chain activities [10]. A study on prestressed concrete panels (PCPs)'s manufacturer in Texas found out that during storage and transportation, uneven or sudden stresses may cause cracks in the PCPs. If the blocks differ in height or are not aligned vertically, bending stresses are introduced in the panels and may cause cracking. Cracks can also be caused if panels are stacked on uneven ground, or if the straps holding stacks of panels to a truck bed are improperly placed and tightened [11].

The survey for KVMRT continues by analysing respondent opinion to reduce defects. Opinion on avoiding cracks revealed that 84% suggest for protection to avoid any movement and uneven load distribution during storage and delivery stage. 10% of respondents stated that to make sure stacking in even load while 6% recommend for inspection during delivery [7]. The researcher implement protection to recognize whether the protecting the segment really can solve crack issue. The item used for protection is gunny sack.



Graph 2.1: Before (Section 1) & after (Section 2) result of using protection.
Source: [7].

Graph 2.1 shows number of occurrence of defects in previous researcher case study with new case study that implement recommended solution. It generally highlights that with protection, cracks can be reduce to 34% [7]. This shows that a simple protection can really reduce crack. Perpendicular to IBS concept, which promotes rapid construction, such defects can still be seen and the result of the research still did not achieve even half of percentage for crack reduction.

2.2 Minimizing material handling

Almost every component and material used in construction is transported on site by mechanized lifting or hauling equipment of one kind or another. The types of lifting equipment that may be monitored include cranes (top-slewing and bottom-slewing tower cranes, crawler, and truck-mounted mobile cranes), hoists, concrete pumps, and material handlers [12]. Material handlers for storage in precast industry include run off carriage, forklift, and palletizer. Most casted concrete will be stacked from its conveyor via forklift. When times comes for delivery, the forklift will again be functioned to move the components into truck. Forklift might have benefits to improve productivity and reduce manual material handling, however, they also result in occupational hazards, especially when there is interaction with pedestrians [13]. Forklift has large amount of interaction with pedestrian workers. Then, it also requires driver's full attention. When carrying a load in reverse, the driver has simultaneously monitored the balance of his load at the back and watch the direction of travel driving with their left hand on steering wheel and right hand on the load control and they must monitor their blind spot [14]. Poor design of machineries will lead to poor posture of handler, leading to driver fatigue and spinal and abdominal trauma [15]. A palletizer is a machine which means for stacking cases of goods or products onto a pallet. Production pallets with freshly poured concrete elements are stacked in a rack. The stacker lifts the pallets onto the required rack level and moves them in and out again. Next,

the run-off carriage is designed to receive the finished wall and floors panels which will then be stored in storage yard. The precast panels can either be transported individually or on transport racks to the open-air storage area. However, open-air storage might expose the precast product to various weather condition, which could affect the hardening process of concrete.

In storage yard, the panels were stacked on wooden blocks ("dunnage") when they were stored and transported (Figure 2.2.1) (Kwon et al., 2014). The use of wooden block in flatbed of the truck will protect both precast panel and surface of the truck. Meanwhile, the KVMRT project in Malaysia is using concrete support for stacking (Figure 2.2.2) [7]. However, researcher found direct contact between the segment and the support can caused spalling. The disadvantages of using timber is that it is not a sustainable element and no control over the quantity. Some might return back to the precaster, while some might negligently missing. Manufacturer will always need to re-purchase.

Figure 2.2.1: Precast panel lifted by forklift and stacked by timber.
Source: [11].

Figure 2.2.2: Precast panel stacked by concrete support.
Source: [7].

Technology has bring forward method of stacking into racking system called finger racking storage. After the panels are manufactured and partially cured, they are stored in the panel racks for additional curing time until ready for shipment. The panels are hoisted into the racks for storage using a forklift or a crane. The panels are positioned close to the finger rack (typically within ½-inch) and held in a nearly upright position using 20-inch-long, number 7 rebar pins that are inserted into the finger rack holes. Wooden wedges, of variable widths and thicknesses, are positioned and hammered between the panel and the pins to further secure the panel in an upright position.

This upright racking system however involves in a fatal accident [16]. The panels in the rack tipped over which resulted in the collapse of the entire system (80 feet long). Some of the pins used were bent, indicating that they were undersized. The pins did not have any retaining mechanism to prevent the pins from being pushed through the tube holes or for ensuring the pins were inserted the proper distance. These clearly illustrated that it has design issue which are not practical to be used.

Workplace transport or machinery is the second biggest cause of accidents in the workplace, accounting for about 70 fatalities each year [17]. Instead of having few machineries to lift a panel, it is more economical to have one rack that can be portable and controlled for motion. Adding artificial intelligent for this rack could ease more on user where the machine can process where it must go and detect any obstacle to reach destination.

2.3 Protective Equipment for Precast Delivery

Manufacturers offer a variety of tie-downs, blocks, braces, etc., for securing cargo, but tie-downs are the most frequently used [18]. Tie-down assemblies may consist of rope, chain, cable, or webbing as well as ratchets, binders, bolts, or hooks. The most important criteria are strength and durability, and tie-downs are rated to aid delivery process. Web straps are popular tie-downs used by multiple industries. Observation has been done and few scenes of precast delivery truck were seen on certain highway spots as shown in Figure 2.3.1 and Figure 2.3.2. A study of crack controlling in Texas precast plant also having strap to secure precast segments on truck as shown in Figure 2.3.3 [11].

Figure 2.3.1: Precast components caught on Ipoh-Lumut Highway.

Figure 2.3.2: Transportation of precast segment on Skudai-Senai Highway.

Figure 2.3.3: Panel strapped to flatbed truck. Source: [11].

The primarily concern on transportation of precast segment is falling. To prevent segments from falling during the journey to site, the segments are supported on timber wrapped with plastic sheets, and tightly secured by ropes and a layer of rubber is put underneath the ropes to give the stack an additional stability [19].

Tie-down can be used to secure equipment, pallets of cargo, or individual items. Compared to steel chains, they are lighter, easier to handle, and less likely to damage cargo. However, rough edges or surfaces can cut or abrade the webbing. Web straps can be purchased in various widths: the greater the width, the greater the load bearing capacity. They are labeled or marked with their own working load limit, set by the manufacturer. Despite having advantages, the strength of tie-down cannot be compared to rigid protection frame or brace. Load falling on the road is serious business. First of all, it's a loss: whatever falls is spilled, damaged, or destroyed. Falling cargo can cause direct or indirect human injury and destruction of personal property. There may be environmental impacts if it falls onto chemical or contaminated subject; and if the insurance doesn't cover the cost of remediation, manufacturer have to pay for cleanup and restoration as well as compensation if involves soul. Accidents still occur with presence of tie-down. Figure 2.3.4 are the accidents occur in Singapore and Malaysia.

Figure 2.3.4: News on precast accidents. Source: [20]

2.3 Human Interference; Unsafe Act

Human errors that could potentially cause an accident are called unsafe acts may be defined to be a human action that departs from hazard control or job procedures to which the person has been trained or otherwise informed, which causes unnecessary exposure of a person to hazard [21]. Wherever human interference takes place, there will be risk of hazards. The safety in workplace is one of the most essential issues that cannot be taken lightly. Some might be minor accident, some may cause serious and huge effect to the organization especially within the industry involved machinery handling including of prime movers, trucks, forklifts and cranes that is very much related with the issue of safety and health awareness [22].

75,000 industrial accident were recorded, 88% of the industrial accidents were caused by unsafe acts, 10% of the accidents were caused by unsafe conditions, and another 2% of industrial were due to unavoidable case; acts of God [23]. Human factors are likely to contribute to this problem on a number of levels including factor relating to individuals (e.g. drivers and pedestrians), the nature of the job (e.g.

design of the workplace and vehicle), and the organisational (e.g. training procedures and management systems) [24]. Study found unsafe act causing or contributing to nearly all injuries [25]. Consideration on machinery selection in plant is important. This is because the ways to store component are also related to safety of labour [26].

METHODOLOGY

Desk study is one of proven data collection method, to gather information on defects during storage and transportation of precast components. This is done by reviewing previous research articles, journal, magazine, books, and bibliography to find out research question. Most articles shall be about defect, loading mechanism and mechatronic sense to create an idea of self-loading suspension rack. Literature review helps to gain understanding for significance of problem solving. Selected articles regarding storage and transportation of precast concrete production were reviewed through online scientific journals publications in online database, Google Scholar and ScienceDirect. Sieving is done throughout the findings and 20 relevant research paper had been reviewed.

Observation is done randomly by capturing any visible precast delivery truck on Malaysia's highways. Few spots have been active with sight of truck that contain precast products. The active spots are Skudai-Senai Highways and Ipoh-Lumut Highway. The probability of occurrence sight of precast delivery truck in Skudai area is due to few precast plants has been established in the area.
Meanwhile, sight of precast delivery truck in Ipoh-Lumut area might be due to highway project in Manjung. Protection guards and any securements for the product on the truck had been identified and analyzed.

ANALYSIS

Suspension element were usually be found in vehicles. However, this study will apply the concept of suspension system for self-loading suspension rack on precast product. Suspension system is the system of springs and shock absorbers by which a vehicle is supported on its wheels. The task of the suspension system is to undertake the shocks that are transferred to the vehicle due to the holes that a moving vehicle's wheels way fall into or bumps that they may come across and as a result, it both protects the vehicles mechanical parts and provides driving comfort [27]. Suspension protects the vehicle and its carriage from damage. Meanwhile, dependent suspension is a type of suspension system where there is a rigid linkage between the two wheels of the same axle. It can bear shocks with a great capacity than independent suspension. Semi-independent system has both the characteristics of dependent as well as independent suspension. The wheel moves relative to one another as in independent suspension but the position of one wheel has some effect on the other wheel [28]. Others benefit of suspension system are such maintaining stability of the vehicle in pitching or rolling, enhance safeguard, preventing the road shocks force transferred to vehicle frame, controlling ride quality, as well as maintaining proper steering geometry.

4.1 Development of Idea by Suspension System

The idea of racking comes from machine that are currently used in the industry. Racking system is about the idea how the product can be stacked, so it can enhance the space utilization when arranging the components. In addition, to include the robotic and mechatronic concept for this innovation, artificial intelligent (AI) has been applied through sensors. Generally, the development of innovation idea comes through combining the concept of rack merging with suspension element and also artificial intelligent. Automation element is added where the self-loading concept allows the rack to be portable and move in controlled condition.

Figure 4.1.1: Idea concept of SLSR.

Design of SLSR can be categorised in two parts. Firstly, the design of loader platform with wheels. It is expected to have independent suspension system. This type of suspension usually offers better ride quality and handling due to less unspring weight. The main advantage of independent suspension is that they require less space, they provide easier steer ability and low weight. Parallel to concept of a truck, the SLSR also being expected to implement air suspension system or pneumatic suspension. The pneumatic itself means something operated with air and gas pressure. An air suspension system uses an air compressor in combination with air struts and suspension air bags to control the feel of the ride [29]. Air suspension systems have long been used in the trucking world, but in the last decade or so, they've moved into the commercial world [.

The second part is the upper segment for the platform where it located stacking rack. Identity for this rack shall be implemented via Radio Frequency Identification (RFID). All data and specification for precast product in the rack can be stored in the RFID.

The design of spring with cushion will be installed throughout the rack for it to hold the precast product. The combination of spring and cushion is functioned as shock absorber. It is implemented to avoid direct penetration of vibration force exerted from the motion during transportation. The design for SLSR were illustrated by computer aid diagram as shown in Figure 4.1.3.

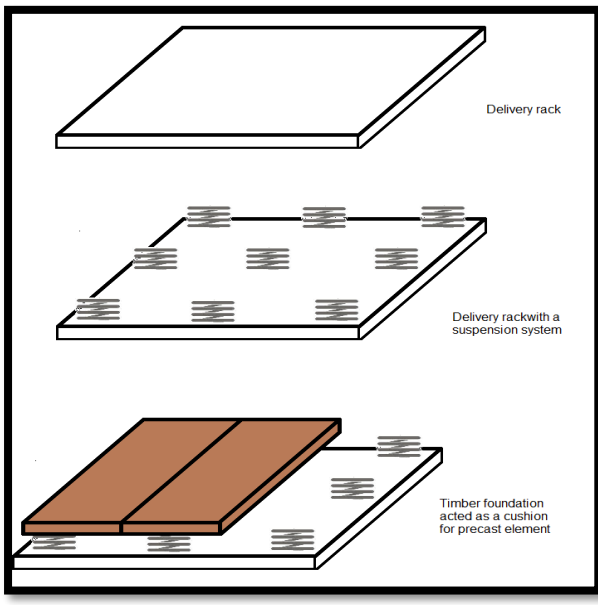


Figure 4.1.2: Basic concept for SLSR design

Figure 4.1.3: Design sketch of SLSR.

The automation element of moving platform shall be programmed with artificial intelligent system. Scanner and sensors mechanization shall work together for motion of the platform. The sensors are expected to be function for locating pathway and detect for pedestrian and obstacle. Semi-auto controller will be implemented in this rack. Ones will need to switch on and off for the operation. The automation part will be shown as it works from production conveyor to storage. Once it has been located in storage yard, it needs to be switch off to avoid any motion. RFID controller will automatically be switched on afterwards. SLSR shall then waiting for command from controller to be delivered to truck. As RFID contains details of the casted product, the controller coordinator will just need to click type of project and SLSR will then activate it system and moves to reach delivery truck.

SLSR will be beneficial for storage space utilization. It will avoid double handling which will cut out the process of precast element to storage and storage to delivery truck via forklift or any run-off carriage. This will eventually cut on cost and time. The suspension element will protect precast panel along the journey to stay rigid and safely delivered. As the precast panel quality being preserve, it will reduce remedies on site. The design has automation element where it needs no operator but only a controller. Thus, this enhance safe working environment for workers.

CONCLUSIONS

Components must have bearers placed at suitable positions along their length, in accordance with the suitability arrangements. Where components are stacked in layers the bearers at each layer should line through vertically, so as to avoid shear planes. The material used for securing the components should be shall be mechanism to ease delivery process. Thus, self-loading suspension rack somehow would contribute a lot in construction industry especially in prefabricating factory. It allows huge cut cost for usage of machineries such as forklift and run off carriage. It provides better storage system of precast panel. Curing can be done easily. Quality can be controlled comprehensively. Furthermore, it can reduce stress effect which eventually creates cracks. The suspension will be functioned as absorber of impact forced to the panel. Lifting would not be a petty thing anymore since the idea proposed self-loading concept. For future improvement, technological evaluation shall be carried out.

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