An Analysis of Formwork Failures and Effectiveness of Safety

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Abstract **- Formwork system in the construction industry plays major role for the construction of cast in situ reinforced concrete structures. The various significant components in the formwork system are lifecycle and operation (not compromising, speed and quality).The various formwork systems available in the market rather than conventional formwork systems are slip formwork, climbing formwork, insulated formwork, reusable plastic formwork etc.,. Failures in the formwork system lead to increase the construction cost, time and manpower. The main aim of the work is to analyze the various types of failures in construction building projects. At first, various types of failures in building construction projects are listed. They are failure within the formwork systems and failure of formwork systems due to external events. In this study, the enabling and triggering events that cause failures in formwork system are identified. Based on the survey internal and external mode of failure in the formwork system can be evaluated. Collected data to be analyzed using statistical tools analysis method, SPSS (Statistical package for the social sciences) is a statistical analysis and data management software package.This paper deals with the analysis of various causes and events to prevent failure in the formwork system and the various safety measures for formwork are analyzed.**

Index Terms –Formwork, Enabling Events, Triggering Events.

I. INTRODUCTION

The construction of a concrete building requires formwork to support. Concrete forms are engineered structures that are required to support loads such as fresh concrete, construction materials, equipment, workers, various impacts, and sometimes wind. The forms must support all the applied loads without collapse or excessive deflection.The formwork must be designed under the quality, safety and economy.The terms formworkand falseworkare often used in combination. Formwork is the total system of support for freshly placed concrete and includes the sheathing that is in contact with the concrete as well as all supporting members, hardware, and necessary bracing. Falsework is a temporary structure erected to support work in the process of construction.Falsework may be the temporary support for steel bridge girders, for precast concrete elements to be post-tensioned together, or for many other applications. The following are the components of formwork.

A. Floor-Forming Systems

Floor-forming systems is a horizontal diaphragm at each level where they occur and transfer earthquake lateral loads to braced walls below that floor level or directly to the foundation when the lowest floor is supported on a foundation.

B. Board Making

Plywood by itself is not enough to take entire loading if it is used for the purpose of formwork. Hence plywood has to be strengthened. The plywood is cut into desired size and shape.Runners of suitable size are fixed to the face of the plywood which does not come in contact with the concrete. The size of the runner depends upon the loads that will be imposed on the formwork.The runners are fixed along edge of the plywood all along perimeter and within these; intermediate stiffeners (runners) are fixed. The spacing of stiffeners depends upon the width of the board, more the width less will be the spacing between stiffeners. This prevents the plywood form bending, warping and bulging.

C.Props

Props are providing at suitable locations for the slab and beam formwork, to impart extra strength to that region of the formwork.Adjustable steel props 2.0 to 3.5m and 2.0 to 3.75m height are used.For increasing the height a propex may be inserted at the top of each steel prop.

D.Primary Runner

It is the wooden runner that runs along the direction of the beam, on top of the stirrup head or the U – jack.

E. Secondary Runner

This is the wooden runner that is kept on the top of the primary runner, perpendicular to the direction of the beam, at spacing as per design. This will support the bottom of the reinforced cement concrete beam has to be cast.

F. Column Forms

Column-form materials tend to vary with the column shape. Wood or steel is often used with square or rectangular columns. Round column forms more typically premanufactured in a range of standard diameters, are available in steel, paperboard, and fiber-reinforced plastic. Square and rectangular forms are composed of short-span bending elements contained by external ties or clamps.

G. Wall Forms

Wall forms principally resist the lateral pressures generated by fresh concrete as a liquid or semi-liquid material. The pressures can be quite large; certainly many times the magnitude of live loads on permanent floors.Walesare long horizontal members used to support the studs. The studs and wales are often wood, steel, or aluminum beam-like elements. Commercial form suppliers are innovative in devising elements as well as hardware for connections. The wall form members are sometimes oriented with the stud members placed horizontal rather than vertical, and the wales are run vertical.

H. Shoring

Shores are vertical or inclined column-like compression supports for forms. Shoring systems may be made of wood or metal posts, scaffold-type frames, or various patented members. Scaffolding is an elevated platform to support workmen, tools, and materials.

I.Bracing and Lacing

A brace is any structural member used to support another, always designed for compression loads and sometimes for tension under special load conditions. In formwork, diagonal bracingis a supplementary (not horizontal or vertical) member designed to resist lateral load. Form braces are frequently made of wood or steel. Commercial steel pipe braces in various diameters and wall thicknesses and load-rated for adjustable lengths are popular. Buckling strength of braces is always a primary design consideration. Horizontal lacing, horizontal members attached to shores or braces to reduce their unsupported length, can thus increase the available load capacity. Both bracing and lacing must be adequately connected at each end. This can be accomplished with bolts, nails, and a variety of commercial devices, depending on the materials involved.

J. Base plate

All supported scaffolds will ultimately transmit their live and dead loads to the surface upon which the scaffold rests. For this reason, the foundation of a scaffold is arguably the most important part of a safe scaffold. It is a part which is used to distribute the load from top to the bottom without slipping.

K. Mudsill

A plank, frame, or small footing on the ground used as a base for a shore or post in formwork. It is a mat of timbers or a small footing on the ground used as a base from which the remainder of the falsework structure is erected.

L. Clamps

U Clamps are used to place span on it. It is used to transfer load from span to props directly. C Clamps are used mainly to hold the sides of the beam and slab in its position without slipping. It will not allow the concrete to increase its size rather than in its exact dimension.

M. Span

Span is mainly used to distribute the dead and live load from the concrete to the props. Extension of span should not be more than two third. Adjustable steel spans of 2.0 to 3.0m and 2.4 to 4.0m are generally used.

N. Other Components

Beam forms are somewhat like short wall forms in that lateral pressure must be resisted; however, they also involve concentrations of vertical load, requiring strong bottom forms and more shoring. Supplementary forming elementsare often incorporated in foundation forms to precisely locate anchor bolts and dowels.

II. TYPES OF FAILURES

The failure types are listed into two types. They are failure within the formwork systems and failure of formwork systems due to external events. Formwork failure leads to accidents in sites causes loss of human life, injuries and overrun of construction cost and time so it is mandatory to do failure analysis of formwork system. Formwork failures are the cause of many accidents and building failures that occur during concrete construction, usually when fresh concrete is being placed. Generally some unexpected event causes one member to fail, then others become overloaded or misaligned and the entire formwork structure collapses. The main causes of formwork failure are improper stripping and shore removal, inadequate bracing, vibration, unstable soil under mudsills (A plank, frame, or small footing on the ground used as a base for a shore or post in formwork), and shoring not plumb, inadequate control of concrete placement and lack of attention to formwork details.

A. Need for Failure Analysis

Formwork failure leads to accidents in sites causes loss of human life, injuries and overrun of construction cost and time so it is mandatory to do failure analysis of formwork system.

B. Causes of Formwork Failure

Formwork failures are the cause of many accidents and building failures that occur during concrete construction, usually when fresh concrete is being placed. Generally some unexpected event causes one member to fail, then others become overloaded or misaligned and the entire formwork

structure collapses. The main causes of formwork failure are:

1. Improper stripping and shore removal
2. Inadequate bracing
3. Vibration
4. Unstable soil under mudsills (A plank, frame, or small footing on the ground used as a base for a shore or post in formwork), shoring not plumb
5. Inadequate control of concrete placement
6. Lack of attention to formwork details.

B. Place & Type of Failure

The place of failure in formwork system based on events is subdivided in to two types.

1. *Enabling Events* - Enabling events are the events which cause failure within the formwork system. The place where the failure takes place are in the foundation, Main Members (Props), Auxiliary members (bracing or lacing) (Props), Platforms, Timber Shore, Timber Joist (Beam), Slab, Wall forms, Form ties, Column, Span, Base Plate, Runners, Sprit Level and Rust.

2. *Triggering Events* – Triggering events are the event which causes failure for formwork externally. They are due to heavy rain (water flow)/river current causing foundation failure, Concentrated/excessive load due to construction material, Effects from concreting operation —vibration, lateral movement, Impact load while concrete pouring, Accidental load from construction equipments/vehicles, Vibration from nearby equipments/vehicles, Effectsof improper/premature formwork removal, Lack of Training for Labor, Use of Unskilled labor, Improper Designand Lack of maintenance.

III. METHODOLOGY PROCESS

A. Working Methodology

- Review the relevant literature regarding formwork failure in construction
- Form the clear methodology about the paper
- Design of questionnaires with the help of field people, literature review and previous failures in construction industry
- Conduct the questionnaire survey
- Analysis the data
- Conclude with suggestion.

This step by working sequence is been given in a flow chart manner below fig: 1.

B. Methodology Chart

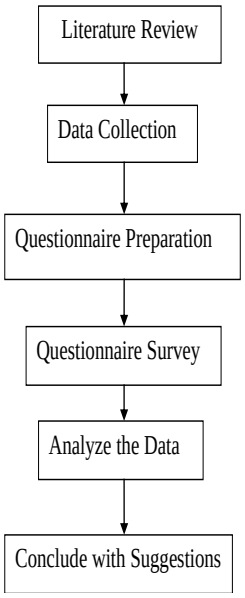

Fig: 1Flow chart of work sequence

IV. QUESTIONNAIRES

A. Design of Questionnaires

A questionnaire was designed to study more about the failure analysis of formwork systems in the construction industry and ways to decrease failure in construction works. Questionnaires are mainly focused on the execution part particularly superstructure. Because the failure of formwork is majorly misplace in execution part. Questionnaire mainly divided into two main categories. They areEnabling events and Triggering events. The questionnaires belonging to enabling events and triggering events are been listed out in table: 1 and table: 2. Questionnaire survey is use to collect data either by direct interview or through mail. Based on a comprehensive assessment of the likelihood of occurrence and their impacts on the project objectives from the data obtained, this identifies the failure factor. The formwork failures which is associated with construction projects and asked respondents to review and indicate the likelihood of occurrence of these faults as very often, often, rare, very rare or none and the level of impact on each project objective that would result in this format. Collected data to be analyzed using statistical tools analysis method, SPSS (Statistical package for the social sciences) is a statistical analysis and data management software package.

B. Questionnaire Survey

1. *Enabling events* - Events which cause failure withinthe formwork system.

Please fill in the blank the number that applies

Performance scale of Enabling Events:

Very Often	Often	Rare	Very Rare	None
1	2	3	4	5

Table 1: Types of failures in enabling events

S.No	Types of Internal Failure	Rank	Rank Index
1.	**Main Members – Props**		
1.1	Inadequate spacing between members		
1.2	Insufficient load carrying capacity		
1.3	Use of defective pin/rod to hold the props at required heights		
1.4	Use of defective C clamps		
1.5	Use of inclined & non rigid props		
1.6	Poor concrete mix laid for shore		
1.7	Improper mudsill installation Mudsill - A plank, frame, or small footing on the ground used as a base for a shore or post in formwork.		
1.8	Use of concrete blocks, size stones, bricks, centering sheets or other materials		
1.9	Dislocation of base plate		
1.10	Use of defective members		
2.	**Auxiliary members - Props (bracing or lacing)**		
2.1	Missing/insufficient auxiliary members		
2.2	Inadequately connected auxiliary members to wall forms		
2.3	Use of defective pin/rod to hold the props at required heights		
2.4	Use of defective members		
2.5	Use of defective C clamps		
3.	**Platforms**		
3.1	Improperly laid platforms		
4.	**Timber Shore**		
4.1	Inadequate spacing between members		
4.2	Use of defective members		
4.3	Insufficient load carrying capacity - low safety factor		
5.	**Timber Joist – Beam**		
5.1	Unstable/improperly installed joists		
5.2	Inadequate spacing between members		
5.3	Use of defective members		
5.4	Use of defective C clamps		
6.	**Slab Shuttering**		
6.1	Disjoint of the soffit forms		
6.2	Side shuttering is not vertical		
6.3	Dislocation of sprit level		
7.	**wall forms**		
7.1	Disjoint of wall forms		
8.	**Form ties**		
8.1	Insufficient load carrying capacity of ties		
8.2	Inadequate spacing of ties		
8.3	Insufficient number of tie rods		
9.	**Column Shuttering**		
9.1	Use of defective members (Plywood)		
9.2	Missing/insufficient number of Runners		
10.	**Span**		
10.1	Use of defective or bent spans		
10.2	Over Extension of span (More than 2/3rd distance)		
11.	**Runners**		
11.1	Use of cracked runners		
11.2	Use of defective U clamps		

2. *Triggering events* -Events which causes failure for formwork externally.

Please fill in the blank the number that applies

Magnitude scale of Triggering Events:

Very Often	Often	Rare	Very Rare	None
1	2	3	4	5

Table 2: Type of failure in triggering events

S.No	Type of External Failure	Rank	Rank Index
1.	Heavy rain (water flow)/river current causing foundation failure		
2.	Concentrated/excessive load due to construction material		
3.	Effects from concreting operation —vibration, lateral movement		
4.	Impact load while concrete pouring		
5.	Accidental load from construction equipments/vehicles		
6.	Vibration from nearby equipments/vehicles		
7.	Effects of improper/premature formwork removal		
8.	Lack of Training for Labor		
9.	Use of Unskilled labor		
10.	Improper Design		
11.	Lack of maintenance		

V. CONCLUSION

A simple procedure for assessing the probability of failure of temporary structures was developed to determine the most probable paths of progressive failures. Knowledge of these failure paths will serve several purposes. First, it will enable a construction engineer to predict potential collapses in temporary structures. The suggestion from the engineers and the expected result of this study will expose the main factors which lead to failure in formwork system. This study will create awareness of formwork failures and safety to all level construction companies especially in building construction sector and also it is useful for minimizing the wastages in material, workmanship, time and cost.

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