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Experimental Investigation of Concrete Performance in Multistorey RCC Buildings Using Mivan Formwork System

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Abstract

This research study explores the properties of fresh concrete and hardened concrete meant for monolithic construction using Mivan aluminium formworks in multi-storey reinforced concrete buildings. OPC, crushed granite coarse aggregate, manufactured sand, GGBS, water and super-plasticizer chemicals were utilized for preparation of M30 concrete mixtures. Proportions of concrete mixes were prepared following IS 10262:2019 guidelines for a water to cement ratio of 0.40. Tests for fresh concrete properties included slump test and slump flow test whereas compressive strength was tested for by making 150 mm cubes after water curing for 7 and 28 days. Target slump flow value of 900-950 mm was achieved indicating good flowability for pouring into Mivan formworks. Compressive strengths obtained for M30 regular concrete were 27.87 N/mm² and 53.03 N/mm² after 7 and 28 days while M30 SDC obtained 28.50 N/mm² and 54.31 N/mm².

Keywords: Mivan Formwork, High-Workability Concrete, Superplasticizer, Compressive Strength, Monolithic Construction, RCC Building.

1. Introduction

In the current era of construction, due to the need for quick, efficient and effective construction techniques, the Mivan formwork system is employed in multistorey RCC buildings. It involves the use of aluminum formworks to facilitate monolithic construction, wherein both walls and slab are cast simultaneously. Concrete holds an extremely important position regarding structural strength and performance.

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Unlike traditional construction technique, concrete in the Mivan system requires excellent workability and flowability of concrete in order to achieve proper filling of formwork without segregation and honeycombing. The formwork is rigid in nature, and thus it needs concrete with good density and uniformity and sufficient strength. The ready-mix concrete along with chemical admixtures like superplasticizers is usually employed in such constructions.

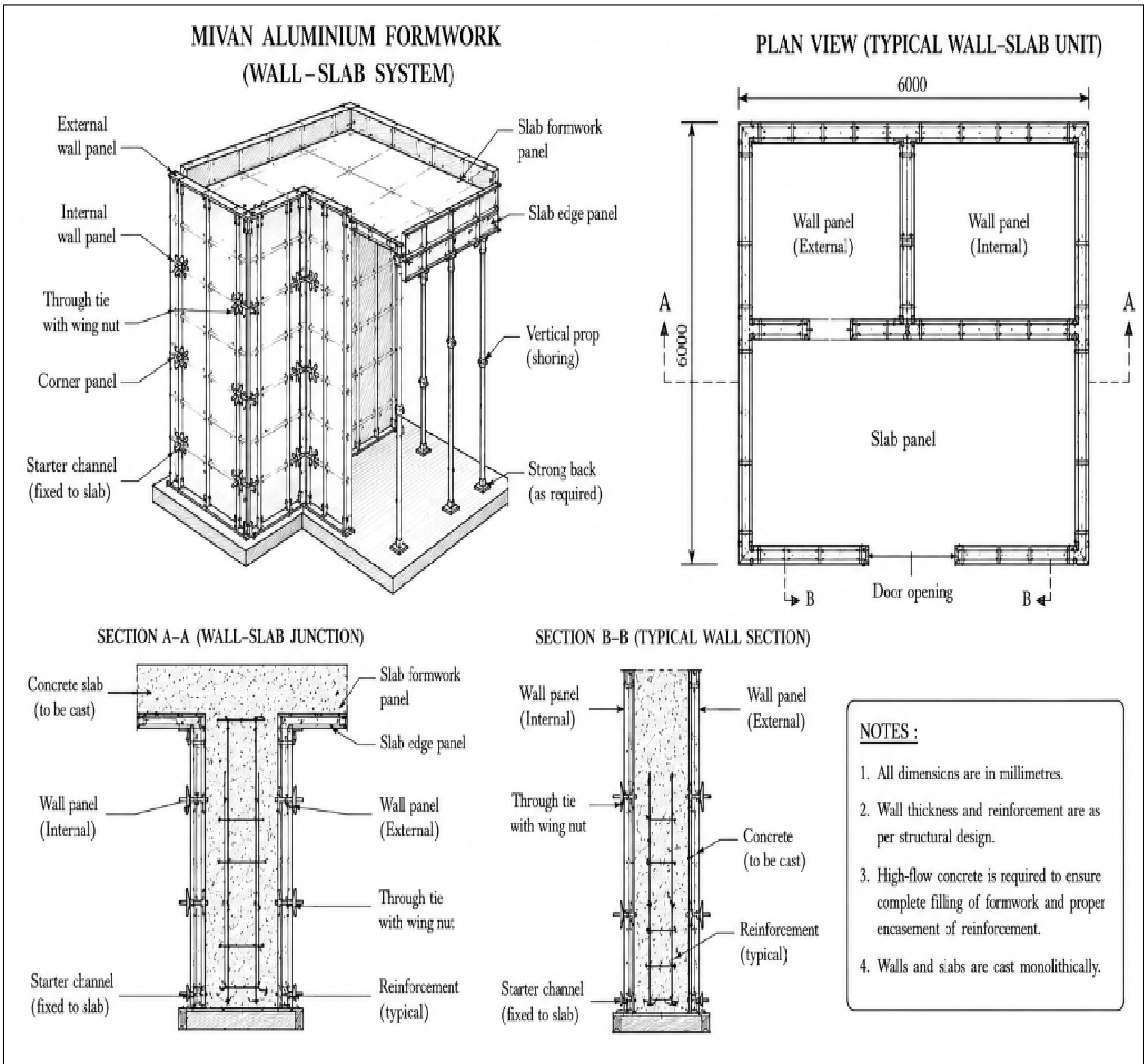

Figure 1. Sketch representation of Mivan aluminium formwork

Figure 1 shows the typical configuration of the Mivan aluminum formwork system used in monolithic wall-slab construction. Due to the quick construction process employed in Mivan construction method, it requires concrete with proper curing period and early strength. Mix design and quality control tests are necessary in monitoring properties like slump flow and compressive strength.

2. Literature Review

With the rapid growth in multi-story building construction, there has been an increase in demand for advanced formwork systems that can enhance construction performance, efficiency, and speed. One of the efficient formworks is the Mivan formwork, which uses aluminium panels for monolithic construction. It has been observed that Mivan formwork system can help achieve faster construction cycle time, enhanced accuracy in dimensions, better surface finish, and labor savings when compared with traditional formworks [1], [2], [7]. Additionally, scheduling research has suggested that the repetition nature of aluminum formwork may enhance completion times in multi-storey buildings [8].

Selection and placement of concrete are especially critical where Mivan formwork systems are used. As monolithic construction is the process of casting structure elements simultaneously, it is necessary that the concrete has suitable workability and flowability to encapsulate reinforcement. Modern knowledge on concrete technology highlights the significance of cement quality, aggregate quality, water-to-cement ratio, workability, strength gain, and durability for ensuring the proper performance of concrete [3]. Technological developments in formwork have added importance to of the selection of appropriate construction materials [4].

The high-workability concrete and self-compacting concrete (SCC) relate to the issues of the contemporary formwork technology due to the possibility of increasing the filling capacity and decrease in difficulties associated with insufficient compaction. As has been shown by experimental studies of the SCC, it is very important to study the characteristics of fresh concrete along with mechanical properties during creation of high-flow concrete mixes [5]. Chemical additives (for example, superplasticizers) allow to increase workability and retain strength through reduction in mixing water.

Durability of concrete in multi-storey RCC building is another major concern that needs to be taken into consideration. Correct choice of materials, mix design, and proper curing and quality control are crucial for providing durability and preventing deterioration [6]. Several studies have shown the benefits of aluminium formwork compared to traditional formwork in terms of construction efficiency, quality and suitability for repeated construction using RCC [7], [9]. Hence, from the literature, it can be seen that construction of Mivan is dependent not only on formwork but also on the concrete.

Though the advantages of the use of Mivan aluminium formwork in the construction process, concerning the faster construction process, accurate dimensions, smooth surface, and saving labor, have already been discussed in many researches before, the requirements concerning the properties of concrete for monolithic construction with the help of this technology have been almost neglected. The main focus of the researches concerns the comparison of Mivan formwork with the conventional formwork, construction period and general technology of concrete. However, the dependence between the high fluidity of fresh concrete and the high strength of hardened concrete concerning the construction of monolithic elements using Mivan formwork was considered rather seldom. To be more precise, it is necessary to conduct an experimental investigation concerning the feasibility of the concrete mix designing in such a way that it can ensure the high fluidity, required for complete filling of aluminum formwork, and, at the same time, sufficient strength development. Moreover, the comparative investigation of regular M30 concrete and M30 SDC concrete with superplasticizer at the same water-cement ratio was not sufficiently made.

The experimental research explores the fresh and hardened properties of M30 concrete to be used in monolithic construction via Mivan aluminum formwork. The following research goals have been identified for the current research:

- Detection of properties of constituent materials necessary for the mixture preparation of concrete.
- Mixture preparation of M30 Regular and M30 SDC (self-displacing concrete) mixtures using appropriate mixture proportions with water-to-cement ratio equal to 0.40.
- Exploration of the slump and slump flow properties of the investigated concrete mixtures for Mivan formwork.
- Determination of compressive strength at 7 days and 28 days for the investigated concrete mixtures.

3. Materials and Methods

The experimental study evaluated the fresh and hardened properties of the concrete that would be used for the monolithic construction through the Mivan aluminium formwork system in multistorey RCC buildings. Two types of M30 concrete mixes, which include M30

Regular and M30 SDC (self-displacing concrete), have been studied. The entire experimental process involved material characterization, concrete mix design, RMC production, fresh concrete test, specimen preparation, and curing, and compressive strength test. The entire process of experimentation carried out in the study is shown in Figure 2.

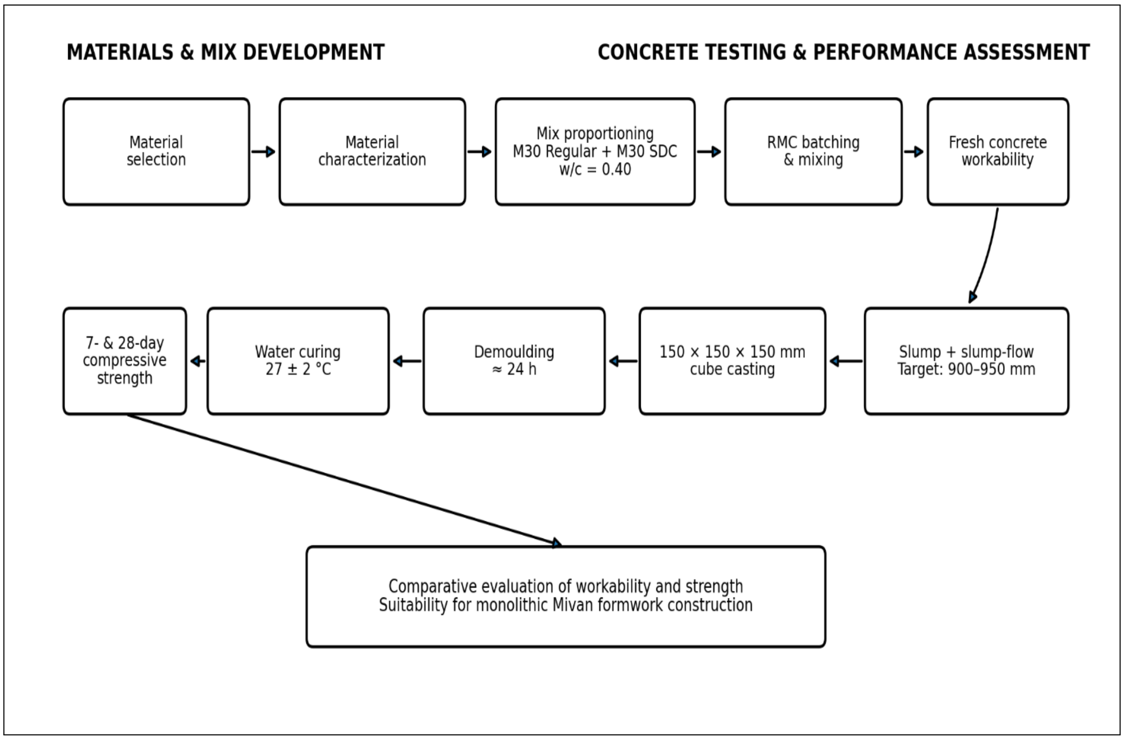

Figure 2. Experimental workflow adopted for evaluation of concrete performance in Mivan formwork construction.

3.1 Materials and Characterization

The concrete mixes were produced using Ordinary Portland Cement (OPC) 43 grade, crushed granite coarse aggregate with a nominal size of 20 mm, manufactured sand (M-sand) that passed 4.75-mm IS sieve, Ground Granulated Blast Furnace Slag (GGBS) as supplementary cementitious material, water, and ECMAS 800 and ECMAS 902s chemical admixture as superplasticizers.

The properties of the materials used in concrete mixes were tested in accordance with Indian standards before producing the concrete mixes. The cement had a standard consistency of 31% with initial and final setting times of 145 and 460 min, respectively. The coarse aggregate possessed a bulk density of 1588.16 kg/m³, specific gravity of 2.78, water absorption of 0.40%, flakiness index of 11.15%, elongation index of 11.40%, and aggregate impact value of 11.21%.

Also, the sieve analysis indicated a well-graded aggregate. The fine aggregate possessed a bulk density of 1594.74 kg/m³, was in Zone II grading, and its silt and clay content were 16.67%. The chemical admixture had a pH of 6.02, dry material content of 15.55%, chloride content of 0.08%, relative density of 1.050, and ash content of 0.22%.

3.2 Mix Proportioning and Experimental Procedure

Two mixtures of M30 grade were chosen as M30 Regular, which serves as a control, and M30 SDC (self-displacing concrete), which is a modified version of the mixture required for achieving the desired flowability of fresh concrete for Mivan construction. Both mixtures were formulated as per IS 10262:2019 based on a water-to-cement ratio of 0.40. GGBS was added as supplementary cementitious material, whereas ECMAS 800 and ECMAS 902s were used as superplasticizer.

Ready-Mixed Concrete (RMC) was utilized for the production of concrete. Cement and GGBS were stockpiled in silos, aggregates in separate bins, and water and chemical admixtures were kept in distinct tanks. Proportional mixing was carried out in a computerized batching process. Fig. 3 and Fig. 4 depict the aggregate storage and batching system and cementitious material storage silos, respectively.

Figure 3. Aggregate storage and batching arrangement at the RMC facility

Figure 4. Cementitious-material storage silos used for RMC production

The fresh concrete mix was tested by means of the slump test based on IS 1199 guidelines, followed by the slump flow test in order to evaluate the flow characteristics necessary for placing concrete in the Mivan Aluminium formwork. Target slump flow value was 900 – 950 mm. After conducting tests on fresh concrete, cubes with dimensions of 150 × 150 × 150 mm were made and kept in moulds for about 24 hours after which they were demoulded.

3.3 Compressive-Strength Evaluation and Applicable Standards

Testing of the hardened concrete was done by determining compressive strength of the cured cubes specimens at 7 and 28 days. Compression testing was carried out using Compression Testing Machine (CTM), following IS 516. Compressive strength of each specimen was determined by the maximum load that the specimen could take before failure, relative to its loaded cross-sectional area, and the strength was reported in N/mm² (MPa).

All experimental procedures followed the relevant Indian Standard Codes of Practice [10]-[15]. IS 10262:2019 was followed for concrete mix design; IS 1199 for test on fresh concrete; IS 516 for compressive strength test; IS 2386 for aggregate test; IS 4031 for cement test; and IS 9103 for chemical admixture test.

4. Results and Discussion

4.1 Concrete Production and Fresh-Concrete Performance

Experimental findings proved that the selected materials can be processed through the RMC manufacturing process used in this study. The batching procedure was conducted in such a way that the aggregates and cementitious materials had their own storage and handling systems, thus enabling the proportioning of the concrete components.

Figure 5. Slump-flow test of fresh concrete

The fresh concrete was found to demonstrate true-slump behavior in the standard slump test. However, more crucially, the flow diameter obtained from the slump flow test was within the target range of 900-950 mm. The resulting spread of flow is depicted in Fig. 5 below. This indicates that the choice of mixture proportions and superplasticizer combination met the requirements of high flowability necessary for concreting in Mivan aluminum formwork. High flowability is important in monolithic concreting, which requires concrete filling of the formwork and even distribution.

The observed fresh concrete behavior fits into the purpose of having the desired water-to-cement ratio of 0.40 using the chemical admixtures in order to get the necessary workability. Hence, the high flowability obtained from the experiment has been attained not by means of increasing the amount of mixing water but through designing the mix and controlling the admixtures. This is significant in order to ensure that the desired performance of the hardened concrete will be achieved.

4.2 Compressive Strength

The compressive-strength results obtained at 7 and 28 days are presented in Table 1.

Table 1. Compressive strength of concrete at 7 and 28 days

Concrete Type	7-day strength (N/mm^2)	28-day strength (N/mm^2)
M30 Regular	27.87	53.03
M30 SDC	28.50	54.31

The compressive strength of the M30 regular mixture had greatly increased at 28 days to stand at 53.03 N/mm² from 27.87 N/mm². This implies an increase of about 90.2%. In a similar trend, the compressive strength of M30 SDC had greatly increased from 28.50 N/mm² at 7 days to 54.31 N/mm² at 28 days. This implied an increase of about 90.6%.

The above data shows the continued strength development in the two periods considered. In 7 days, M30 SDC showed about 2.3% greater compressive strength compared to M30 regular concrete. In 28 days, the increase was 2.4%. Even though the difference between the two M30 concrete mixtures considered is very small, the mixture of SDC gave higher compressive strength at the two test periods.

Figure 6. Compressive-strength testing of concrete cube specimen using a CTM.

Figure 6 illustrates the setup for the compressive strength test. Utilization of 150 mm cubes and testing at the ages of 7 and 28 days made it possible to assess early and late age strengths development. Early age results become especially important when considering rapid construction methods since the early age strength can affect construction cycle, while the 28-day results will be the basis for assessing developed strength of hardened concrete.

4.3 Integrated Discussion

From the above findings, it can be concluded that the concrete tested is in accordance with the requirements regarding its properties of flowability and strength needed for the application in Mivan construction technology. The obtained slump-flow values in the range of 900-950 mm show that the concrete had proper flow ability for placement in the aluminum formwork. Such behavior and true-slump behavior in standard workability tests show proper flowability of fresh concrete under the mentioned experimental conditions.

Moreover, the strength results show that the high workability of concrete does not influence its compressive strength negatively. Both M30 mixes were more than 50 N/mm² after 28 days. The concrete mixtures M30 regular and M30 SDC showed the compressive strength of 53.03 and 54.31 N/mm², correspondingly. The strength in 7 days was also quite high: 27.87 and 28.50 N/mm², correspondingly.

The relatively small gap between the values of the compressive strengths of M30 regular and M30 SDC concretes proves that there were no negative effects on the compressive strength as a result of the application of the altered concrete condition and that the desired level of flowability of fresh concrete was achieved.

In general, the experimental results prove that the researched concrete possesses high flowability of the fresh state and satisfactory compressive strength development. All in all, the combination of the controlled RMC production, good workability, and sufficient hardened strength shows the potential suitability of the concrete for monolithic Mivan construction. The current experimental data, however, are confined to fresh concrete workability and compressive strength only; hence, any generalization about its durability must wait for further experimental data in this respect.

5. Conclusion

From the conducted experiment, it is evident that the designed concrete mixtures have the potential of meeting the high flowability and compressive strength specifications needed to construct monolithic concrete structures using the Mivan aluminium formwork. The employed RMC production and batching process offered an ideal environment for making consistent fresh concrete. Slump flow values of 900–950 mm was recorded, which is sufficient flowability to fill the aluminium formwork. For the M30 regular concrete, compressive strength values of 27.87 N/mm² at 7 days and 53.03 N/mm² at 28 days were recorded while those for the M30 SDC were 28.50 and 54.31 N/mm² at the same respective curing period. It is evident from the results that strength continues to develop, and the SDC mixture outperforms the M30 regular concrete in terms of strength.

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