Optimization Of Ready Mix Concrete (RMC) Dispatching Schedule: A Literature Review

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Abstract - Considering the infrastructural development in India over past decades, especially in Maharashtra due to industrialization and urbanisation, the construction sectors rules the Indian economy. Concrete being most popular material of the construction sector, concrete batch plants will see a massive growth in line with the infrastructural expansion [1]. Delivering Ready Mixed Concrete (RMC) to construction sites is an important task of RMC batch plant manager. The RMC batch plant manager has to prepare an efficient schedule of dispatching RMC trucks, which will optimizes the operations at the construction sites and also at the batch plant. This is because of time limitation of RMC delivery which is 1.5 hrs, the dispatching manager has to consider both time and flexibility while matching up the working process at different construction sites that calls for delivery. The existing dispatching schedule mainly depends on the experiences of the dispatching manager and preferences from site. Whatever logic the plant manager applies for dispatching RMC trucks to the required construction site it may results in the waiting of RMC trucks at one site and keeping other sites waiting for the arrivals of RMC trucks, called as 'interruption'. Hence there is a need to develop a systematic model that incorporates soft computing techniques, to find optimal dispatching schedule which not only will provide the "Un-interrupted" dispatching schedule but also minimizes the total waiting time of RMC trucks. This paper tries to give an overall idea of the research work done till date in this area along with the hurdles in dispatching and also to suggest the scope for the future research work.

Keywords - RMC optimization, Ready Mix Concrete dispatching schedule optimizer, Literature review for RMC dispatching, hurdles in RMC dispatching.

I. INTRODUCTION

Ready Mixed Concrete (RMC) was first introduced into the construction industry in the early 20th century and has been ever since widely employed. To expand the service of RMC without establishing high cost batch plant at the construction site, the RMC truck was invented to deliver RMC to the construction site. Because of time limitation of RMC delivery, the RMC plant manager usually needs to consider both timeliness and flexibility while matching up the working processes at different construction sites that calls for RMC deliveries. From business point of view, the RMC batch plant manager dispatches as many as possible the RMC trucks to different construction sites to maximize the production and profits of the plant. However, the job site manager usually wants to avoid discontinuous (interrupted) RMC casting by requiring a substantial number of RMC trucks waiting in queue at the construction site. Consequently, the batch plant manager usually dispatches RMC trucks based on his or her experiences, which may be inefficient and might present the loss of potential profit. The basic problems of dispatching are interruptions in dispatching, more waiting time, tracking of the vehicle at required incident, satisfying the demands, time limitations, varying demands on every day, type of mix required, road traffic and number of trucks available at plant. With all these problems to be overcome and to find an efficient and uninterrupted dispatching schedule in terms of balancing the production of the construction sites and the batch plant is a great challenge for the batch plant manager.

II. RESEARCHERS COMMENT

Recently, RMC delivery has become more efficient by applying GPS (Global Positing System) to the dispatching process. However, because of numerous dispatching sequences and various impact factors, such as delay of casting concrete at the job site, load limit of RMC trucks required by the law and travel duration between job sites and the batch plant, determining an efficient dispatching schedule of RMC trucks is not an easy task. Recently, RMC delivery has become more efficient by applying GPS (Global Positing System) to the dispatching process. However, a systematic model that optimizes the RMC dispatching schedule is still need to streamline the dispatching process [2].

Ready mixed concrete (RMC) accounts for an increasingly high proportion of the concrete consumed on residential building, heavy and highway construction projects. Compared with on-site mixed concrete, RMC affords the advantages of stable quality, less pollution and less working space requirement, which are of significance to many construction sites, especially those in crowded large cities such as Hong Kong, Beijing and Tianjin. In these cities, many central concrete plants are in operation and more are being established in order to meet the growing demand of concrete in construction sites. A study benchmarking the performance of concrete placing in buildings (covering Hong Kong, Beijing, UK, and Germany) has found that metropolitan areas typically adopt the one-plant-multi-site RMC production and supply system; site productivity is influenced not only by the placing method and other site factors but also by an inevitable imperfect concrete supply. Timely concrete delivery by truck mixers on site contributes to not only continuous, productive site operations on the side of contractors, hut also the cost-effective utilization of limited truck mixer resources on the side of the plant. Hence enhancing the coordination between a RMC plant and

the sites is as critical to improving the productivity of the placing operation, as enhancing the efficiency with which sites and the RMC plant are separately managed. In order to become profitable and competitive, it is also crucial for a RMC business to be able to deploy less truck mixer resources and marshal more efficiently its truck-mixer fleet in running its daily operations [8].
As per the experts comment (Mr. Sham bargi, Partner, Dwarka Agencies, India) in Cover story, Indian Cement Review (December 2013), Current production of RMC is around 15 to 20 million M^3 per year as against a total concrete market of approximately 300 million M^3 per year. In terms of volume, the RMC market has grown around 25 % to 30 % since last one year. This proves the demand and need of the RMC batch plants in India, especially in Maharashtra because of the Infrastructural Development.
In modern construction, Ready Mixed Concrete (RMC) is one of the most popular building materials in construction industry. RMC is prepared generally in a concrete batch plant and ingredient materials for concrete production are weighed and mixed by automated devices consistent with the request of the construction sites. Accordingly, RMC is convenient for all types and all sizes of construction. RMC has several benefits compared to concrete prepared by conventional methods. Regrettably, RMC cannot stock at a batch plant, because of the quick solidifying nature of the concrete. RMC usually needs to be poured within approximately 1-2 hrs. after being produced by the RMC batch plant. That limits the service area of the RMC batch plant. Consequently, RMC industry is concern about production scheduling and truck dispatching. Production scheduling and truck dispatching can be done manually by experienced staffs. Effective production scheduling and efficient truck dispatching are considerable issues for a carrier's RMC plant and construction site management, requiring the carrier to address both timeliness and flexibility, while satisfying construction site operating constraints. For that reason, the distribution of RMC is a complex problem in logistics and combinatorial optimization [9].
The cement consumption of the RMC industry in the United States grew from about one-third to two-thirds of U.S. cement production from 1950 to 1975 (Gaynor 1994). Cement consumption increased to 69% in 1990 and 75% in 2000(NRMCA 2001). The U.S. RMC produced 242 million cubic yards of concrete (184 million m3) in 1990, which increased to 395 million cubic yards (300 million m3) in 2000 (NRMCA 2001). If the average price of concrete is taken as $60.00/cu yd, the estimated revenue of the RMC industry was $23.7 billion in 2000. This is a large amount of money that requires careful consideration. Therefore, optimizing the RMC batch plant operation will lead to appreciable savings in such an important element of the construction industry. Two situations may govern the selection of RMC for a particular project: (1) the site is congested, which is the case for residential building sites where there is little room for mixing concrete and storing cement and aggregate; and (2) the location of casting concrete is continually moving. The concrete can be mixed in a batch plant offsite (RMC) or in a batch plant onsite (CMP) and then transported by transit mixers (Miniger 1969; Strehlow 1973, 1974; Haney 1985; NRMCA 1995; Camillo 1996; Peurify et al. 1996). Therefore, both the concrete batch plant and the transit mixers are key elements of the CMP and RMC operations. This study presents a linear programming (LP) model to optimize their operation [11].

III. LITERATURE REVIEW

1. Bee Colony Optimization

There have been only few studies in the literature dedicated to RMC production or truck dispatching scheduling. Several models for simulating the construction operation have been developed (Cheng and Feng, 2003; Lu *et al*., 2003; Zayed and Halpin, 2001). Furthermore, the efficient and flexible models based on optimization techniques were proposed (Naso *et al*., 2004; Zayed and Minkarah, 2004; Yan *et al*., 2008). In the past decade, various natural inspired algorithms were developed, such as Simulated Annealing (**SA**) (Aarts and Korst, 1989), Genetic Algorithm (**GA**) (Holland, 1975; Goldberg, 1989; Gen and Cheng, 1999), Tabu Search (**TS**) (Glover, 1989; 1990; Bland and Dawson, 1991) algorithm and Particle Swarm Optimization (**PSO**) (Kennedy and Eberhart, 1995; Eberhart and Kennedy, 1995), They are probabilistic heuristic algorithms and have been successfully used to address combinatorial optimization problem. These algorithms can provide better solution in comparison to classical algorithms. A branch of natural inspired algorithms known as Swarm Intelligence (**SI**) is focused on insect behaviors in order to develop some met heuristics, i.e., Ant Colony Optimization (**ACO**) (Dorigo *et al*., 1996), PSO. Bee Colony Optimization (**BCO**) was proposed by Karaboga (2005). It is relatively a new member of SI. The BCO algorithm mimics the food foraging behavior of swarms of honey bees. Honey bees use several mechanisms like waggle dance to find optimal location of food sources and to search new ones. This algorithm is a very simple and robust stochastic optimization algorithm.

2. Genetic Algorithm (GA) for Optimization

A model that incorporates GA and simulation technique is built to find the optimal dispatching schedule which minimizes the total waiting duration of RMC trucks at construction sites and satisfies the needs of RMC deliveries requested by different construction sites. In addition, a user-friendly computer program is developed to help batch plant managers to simplify the dispatching process. Results show that this new approach along with the implemented computer program can quickly generate efficient and flexible schedules of dispatching RMC trucks.
Excellent text on GA is given by Goldberg (2013) and several researchers gave summaries of the essentials of the genetic algorithm modeling (Deb, 1995). Genetic algorithm (GA) is a heuristic technique based on the biological concept of survival of the fittest. This technique has been proven as more effective at identifying high-quality solutions than the analytical techniques previously indicated and it does not require continuity of the objective function or other assumptions such as convexity.
[15]Tarek and Halpin (2001)**,** have applied simulation techniques to concrete batching operation to analysis alternative solutions and recourse management. They applied Micro-CYCLONE [Fig.1], simulation system. They have presented one concrete batch plant example as a case study and demonstrate its usefulness as a decision making tool for plant manager. Also explained the role of simulation as a tool for decision making and resource management. Simulation sensitivity analysis is used to generate useful decision making tool for concrete batch plant operations. The TCQ and contour lines charts were used for establishing production time, production cost, required resources for required distances from batch plant. The feasible region chart is used

for deciding the range of alternative solutions available to minimize production time and cost according to the transportation distance.

The simulation approach is used to study the concrete batch plant operations, which provides a means of predicting system production and defining optimization supply areas around a concrete batch plant.

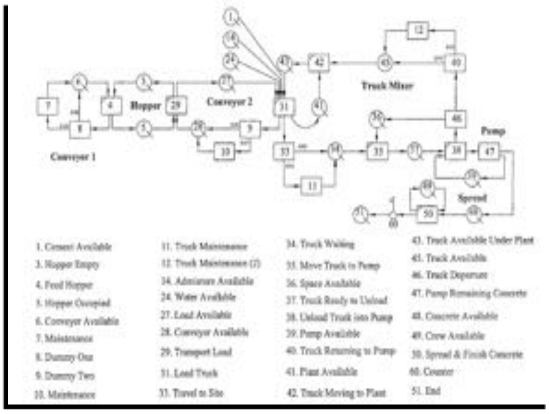

Fig. 1 Micro CYCLONE Schematic Model for Concrete Batching Plant Source (Zayed et al. 2001)

The sub-objectives of this study were:

- Study each component of plant-truck-pump cycle.
- Development of Micro-CYCLONE model for these processes (Fig**.** 1)
- Data collection for simulation to calculate optimum Number of trucks, optimum supply area around batch plant, optimum cost per unit and developing a decision making tool for concrete batch plant manager.

[3]Chunge Wei Feng and Tao-Ming Cheng (2004), developed user friendly computer program called RMCDiSO [Fig.2], to help batch plant manager to streamline the dispatching process of RMC trucks in 2003. Due to the uncertainty and complexity involved in the dispatching schedule/process, if done manually, they thought of such an approach which will ease the batch plant manager to develop as efficient and flexible dispatching schedule of RMC trucks.

They firstly analyzed the factors, which impacts the RMC deliveries, then build a model based on the Genetic Algorithms (GA) and simulation technique to find the best dispatching schedule, which will minimize the total waiting time of RMC trucks at sites and satisfies the needs of the RMC deliveries from different construction sites. Results of the program shows that, the batch plant manager can quickly generate efficient dispatching schedule of RMC trucks, which will improve the operations at batch plant and also promotes the service of the RMC batch plant.

[9]Ming & Zang (2004) have presented a new approach for concrete plant operations optimization by combining RMC production simulation tool (called HKCONSIM) with a GA based optimization procedure.

The main aim of the study is how to apply operation simulation and GA optimization to resource planning and production planning of a RMC plant in order to achieve better plant-site coordination and to meet the daily demands of sites for concrete.

Fig. 2 RMC Dispatching Schedule optimizer Source (Feng Et al. 2013)

The emphasis is given more on:

1. The estimation of number of trucks with certain volume/capacity
2. The estimation of the inter arrival time of consecutive truck mixers (i.e. supply rate)
3. Timely delivery on each sites (service level)
4. Utilization of resources available at batch plant.

3. Supply Chain Management for Optimization:

[2]Chung Feng, Tao Ming Cheng and Tang Wu (2003), found a need of developing a systematic RMC dispatching model based on the dispatching center approach to find the optimum dispatching schedule.

He first explained the SCM (Supply chain Management) concept applied to the model development and then incorporates the SCM concept in building a systematic RMC dispatching model, based on dispatching center approach. This integrated dispatching model allows the dispatching center to take requests from various construction sites and coordinates it's subordinate batch plant to process RMC deliveries in dynamic environment.

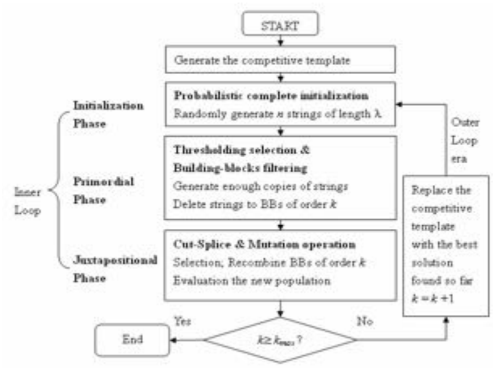

Fig. 3 Organization of the fmGA Source (Feng et al. 2006)

New technologies like fmGA (fast messy Genetic Algorithms) [Fig.3], simulation and GPS (Global Positioning System) [Fig.4] were used within the model development.

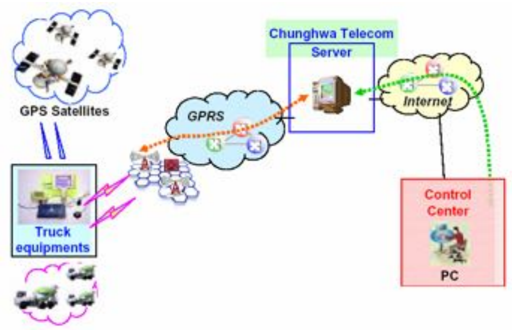

Fig. 4 The GPRS-based GPS Souce (Feng Et al. 2006)

The various SCM concepts like:

- JIT (Just In Time)
- QR (Quick Response)
- BTO (Built to Order) are incorporated in the model and the dispatching center that co-ordinates the various RMC batch plants to deliver RMC to the construction sites has became call center of the RMC delivering operation. All RMC delivery required from the construction sites are processed through the dispatching center, which will direct the trucks from various batch plants to the sites requiring RMC.

4. Variable Neighborhood Search (VNS) for Optimization

[6]Fritz Payr and Verena Schmid (2009), developed a mathematical model for the problem of RMC delivery and provide a solution for it on VNS. The overall goal was to deliver the concrete to site on time and as cost-effective as possible.

In all case studies explained in the model only reasonable combinations of fixed variables are allowed from which the delivery is made and this may be guaranteed by the data-preparation module.

IV. NEED OF THE RESEARCH

Following are the reasons stating the need for more research in this area,

a. No Finished Products in Stock

There are no finished products in stock at the RMC batch plant. Because of the faster solidification of the concrete, RMC cannot be manufactured in advance and should be produced at the time that the job site manager requires the delivery. Such an on call process forces the batch plant manager to develop a flexible scheme which is able to quickly response to the requests from the construction sites.

b. Peak Hours of Dispatching

In practice, there are two types of RMC requests from construction sites. One type is that the construction site places it's order in advance. Another type is the last minute order from the construction site. In addition, the requests of RMC deliveries from different construction sites usually come very close in time. As a result, the RMC batch plant is very busy at certain working hours. This kind of characteristic forces the RMC batch plant manager to quickly determine the RMC delivering schedule which satisfies the needs of different construction sites. However, generating an efficient schedule of dispatching RMC is far from trivial since the complexity and uncertainty involved within the dispatching process.

c. Limited Service Areas of RMC Trucks

RMC usually needs to be casted within 1.5 - 2 hrs after being produced by the RMC batch plant, which limits the service areas of the RMC batch plant. This casting is to be done without any interruption in concreting. Sometimes the batch plant has seven or more sub batch Plants, so as to cover the whole area and delivers the RMC efficiently and effectively.

d. Revenues and Costs

For a batch plant, most of revenues come from selling RMC. More the amounts of RMC delivered to job sites, the more revenues that the batch plant can receive. Although raw materials, such as sand, cement and aggregates presents important costs to the batch plant; the costs related to operating RMC trucks could be more critical.

There are two major types of costs associated with RMC trucks. One is the cost of owning and maintaining RMC trucks. Another is the opportunity cost because of the improper dispatching schedule.

Because discontinuously casting RMC, results in bad quality of concrete, the construction site manager usually calls for a substantial number of trucks to standby at the job site. To serve the customers, batch plant manager might send a substantial number of trucks to the job site as requested. However, such a dispatching approach usually results in to shorthanded with RMC trucks to be dispatched when the other construction sites call for RMC deliveries at the same short period of time.
In addition, from the productivity's perspective, any duration that RMC trucks wait at the construction site should be treated as a waste of time and represents the cost of the opportunity. Therefore, an efficient, uninterrupted and balanced schedule of dispatching RMC trucks not only reduces the opportunity cost of dispatching operation but also minimizes the cost of owning and maintaining RMC trucks.

V. FACTORS AFFECTING DISPATCHING SCHEDULE

RMC to be dispatched to various construction sites is varying day to day, due to varying demand of the sites, locations of the sites, type of concrete required and type of concreting work going on sites. There are various factors which are to be considered while deciding the dispatching schedule like:

i. Mixing Duration 'md'

It is the time required for the Batch Plant to prepare the type of mix required for that particular site and load it to the truck. This also depends on the following two aspects:

- **Type of Mix Required**
- **Capacity of the Batch Plant**

Higher the capacity of the Batch plant lesser is the mixing duration and vice-versa.

ii. GO/BACK Time

This is the time duration required for the truck to reach the construction site (called as GO time) and again to come back to the batch plant (called as BACK time). This varies from site to site and mainly depends on the distance of the construction site from the batch plant. This time duration is calculated by considering the average speed of the truck in between 30 to 40 Kmph. Generally the Go time is less compared to the BACK time as the truck is empty while coming back to the batch plant and weight of the truck is less too.

iii. Casting Duration 'CD' at Site

This is the time required for the casting i.e. unloading the truck at construction site. Because faster the casting time faster is the dispatching schedule for this particular site, which will affect the dispatching schedule.

iv. Allowable Buffer Duration 'ABD'

The RMC loaded in the RMC truck is to be unloaded within 1 hrs. to 1.5 hrs., which not only limits the service area of the plant, but also limits the waiting duration of the RMC trucks at construction site. The ABD (Allowable Buffer Duration) can be calculated by subtracting GO, BACK and CD times from 1.5 hrs.

v. Number of Deliveries Needed 'ND' / Volume of concrete Needed 'Vol'

This is the major factor which governs the dispatching schedule of the RMC truck. This also depends on Volume of Casting and Capacity of Truck. The logics giving the solutions on volume (Vol) base are more effective compared to the number of deliveries (ND) approach.

vi. Number of Trucks Available at Batch Plant 'n'

Higher the number of trucks at batch plant more flexibility in the preparation of the dispatching schedule.

vii. Start Time of Casting (STC)

Generally in India the casting is started in the morning from 7am to 11am. But in some extreme conditions it can be up to 4pm.

viii. Other Factors

There are some other parameters which cannot be considered, while preparing the dispatching schedule, like: Breakdown of Truck, Breakdown of Pump, Breakdown at Plant, Accidents, Traffic Problem or No Entry, Mix design Issues, Climatic conditions (like Rain), Labour problems and Political Issues etc.As these factors cannot be predicted before scheduling, so not be considered while preparing the Dispatching Schedule of RMC truck.
The effects of some of these factors on the optimization have been studied in many literatures. However, few of them are required to be studied extensively.

VI. SCOPE FOR FUTURE WORK

1. Scope for the batch plant manager to make changes in the dispatching schedule can be given to have flexibility in the prepared schedule,
2. Scope to the batch plant manager to prepare the dispatching schedule on single window of computer without any pre-requisite knowledge of the software,
3. Work can be done in optimization on number of RMC truck to be used,
4. Less work on use of GPS technology to track the RMC trucks locations and its actual speed of delivery,
5. Scope can be given to the batch plant manager to prepare the scheduling on mobile / tab, so as to prepare the scheduling in his absence on batch plant.
6. Scope of the work to prepare volume based dispatching schedule to further reduce the waiting time,
7. Advanced evolutionary optimized techniques can be used for the optimization of dispatching schedule, to compare obtained results with industry thumb rules. The advanced evolutionary optimization techniques are:
    a. Genetic Algorithms (GA)
    b. Social Behavioral Based Optimizations:
        » PSO (Particles' Swamp Optimization)
        » BCO (Honey Bee Colony Optimization)

» Ant Colony Optimization (ACO).

Lot of research work has been done in this field of optimization of dispatching schedule of RMC trucks, by various persons worldwide, but yet the technique is not so simple or user friendly. And even there is lot of scope to provide an uninterrupted dispatching schedule by giving scope to the Batch Plant Manager to make changes in the decision making parameters.

VII. CONCLUSION

From the various literature reviews and the study for the scope of the work in this area of dispatching schedule problem, it can be concluded that, the RMC industry is in boom and there is lot of demand for the RMC production and its dispatching in the coming era. If the problem of providing an efficient, flexible and un-interrupted dispatching schedule is overcome through any of the techniques suggested earlier with the modifications stated in the scope for future, the RMC industry can make a revolution in the infrastructure development of the country.

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