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A review on optimization techniques used in civil engineering material and structure design

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ABSTRACT

Optimization of blend extents for materials like cement, contain numerous constituents and are regularly dependent upon a few exhibition, limitation, can be troublesome and tedious errand. Factual trial structure and investigation techniques have been grown explicitly to advance blends. The exhibition of specific materials like cement or mortar changes with change in climatic conditions. Thus, it is important to plan an ideal solid blend as indicated by change in climatic condition. Optimization problem formulation, strategies for enhancement and arrangement methods are displayed. Populace based strategies are likewise clarified. Optimization utilizing imperatives as far as dependability is seen as best choice for enhancing structures with discrete parameters.

Selection and of the scientific committee of the 10th International Conference of Materials Processing and Characterization.

1. Introduction

"Optimization is the demonstration of ideal the best outcome under given conditions" in plan, development and support of any building framework, engineers need to take numerous mechanical and negligible choices at a few phases. A definitive objective of such choices is either to limit the exertion required or to amplify the ideal advantage. Since the impact required or the advantage wanted in any handy circumstance can be communicated as specific choices variable, streamlining can be characterized as the way toward finding the conditions that give the most extreme or least estimation of a capacity. Structure of most building frameworks is a genuinely mind boggling process. Specialist would attempt diverse preliminary structures with the journey of landing at a plan that is ideal. It is conceivable to define the building plan issues as advancement issues with the goal of limiting the expense or weight subject to fulfilment of all states of structure. The optimization algorithms have been introduced in this section. These algorithms are; Genetic Algorithms (GA), Harmony search (HS), Artificial Bee Colony (ABC), Tabu Search (TS), Teaching– Learning-Based Optimization (TLBO), Particle Swarm Optimization (PSO), Big bang – big crunch (BBBC), Charged System Search (CSS), Cuckoo Search Algorithm (CSA), Ant Colony Optimization (ACO), Jaya, Firefly algorithm (FA), Simulated Annealing (SA), Cultural Algorithm (CA), Differential Evolution (DE), League championship algorithm (LCA), Backtracking Search Algorithm (BSA),Glowworm Swarm Optimization (GSO), Memetic Algorithm (MA), Greedy Randomized Adaptive Search Procedure (GRASP), etc. In addition to these algorithms, similar algorithms derived from these algorithms have been developed by the researchers such as elitist TLBO and intelligent GA. In the multi-objective optimization problem, the name of the existing optimization algorithm may be changed as NDS-GA (non-dominated sorting genetic algorithm).

The achievement of basic advancement during the previous decades propelled the development of multidisciplinary plan optimization (MDO) as of late. The multidisciplinary plan enhancement is a field of building those utilizations improvement strategies to take care of basic structure issues consolidating various controls. It is conceivable to fuse all the necessary trains at the same time. The ideal of such issues is better than that of successive enhancement of each control. A significant part of the ideal plan process is the detailing of the structure issue in a numerical organization which is worthy to an optimization calculation. It includes the determination of plan factors, requirements, goals, and models of orders. A classification of different optimization techniques commonly used for design of civil engineering structures and materials design is depicted in Fig. 1.

Table 1 subtleties the optimization algorithm and their first unique papers are given. For instance in Fig. 2. the genetic

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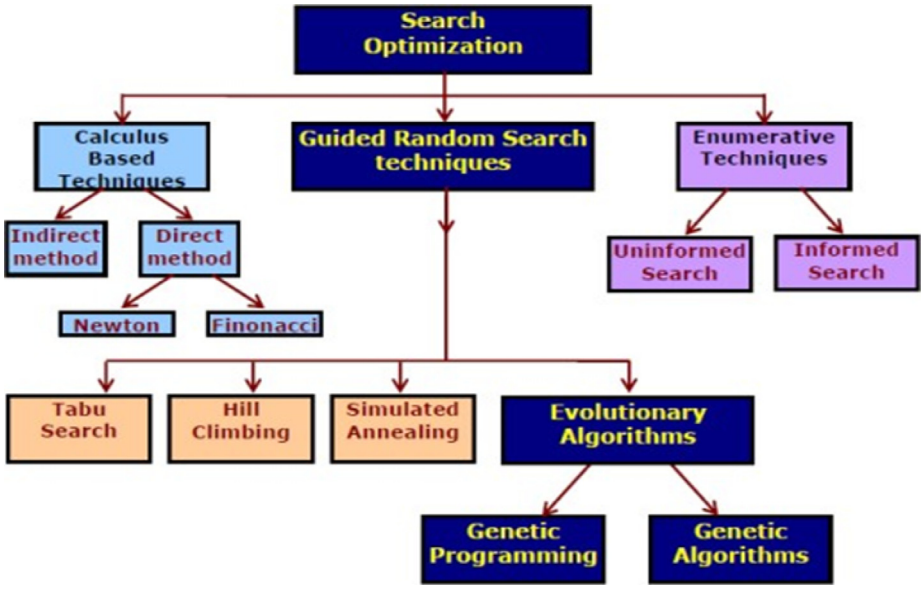

Fig. 1. Classification of different optimization techniques (Subramani & Vijaylakshmi, 2016).

Table 1
A Literature Summary for Different Optimization Techniques Used in Civil Engineering (Dede et al. 2018).

Name	Authors of original paper	Year	References	Related Papers
SA	Kirkpatrick S, Gelatt CD, Vecchi MP	1983	[13]	[24,26,38,39,75,81]
GA	JH Holland	1975	[1]	[25,26,31,35,36,42,44,60,64,70]
TS	Fred Glover	1989	[4]	[77]
ACO	Marco Dorigo	1992	[10]	[37,40,51,52,57,61,62,100]
CA	Robert G Reynolds	1994	[14]	[23,79]
PSO	J Kennedy, R Eberhart	1995	[6]	[26,29,30,32,43,47,54,55,58,59]
DE	Rainer Storn, Kenneth Price	1997	[15]	[53,108]
HS	Zong Woo Geem, Joong Hoon Kim, GV Loganathan	2001	[2]	[34,41,63,76,82,26]
BBBC	K Erol Osman, Ibrahim Eksin	2006	[7]	[106,107]
ABC	Dervis Karaboga, Bahriye Basturk	2007	[3]	[71,72]
CSA	Xin-She Yang, Suash Deb	2009	[9]	[32,91]
LCA	Ali Husseinzadeh Kashan	2009	[16]	
GSO	KN Krishnanand, D Ghose	2009	[18]	
CSS	A Kaveh, S Talatahari	2010	[8]	[104,105]
FA	Xin-She Yang	2010	[12]	[32,34,78]
TLBO	R Venkata Rao, Vimal J Savsani, DP Vakharia	2011	[5]	[69,73,74,83,87,90,103]
BSA	Pinar Civicioglu	2013	[17]	
Jaya	R Venkata Rao	2016	[11]	[96–98]

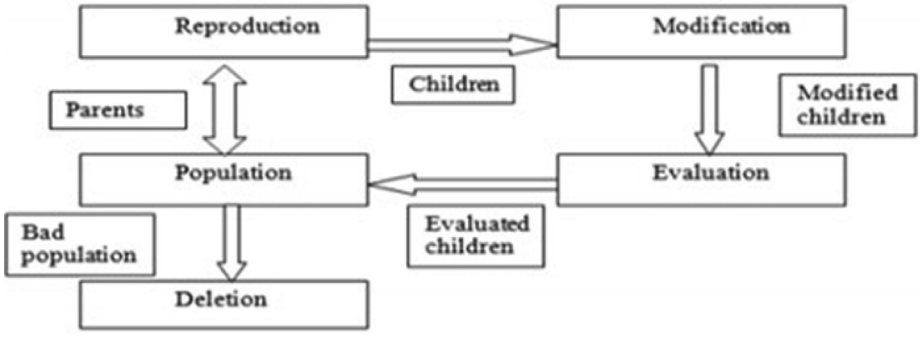

Fig. 2. Genetic Algorithm Optimization Process Flow (Lin, Tsai & Yu, 2012).

algorithm optimization apparatus begins with a haphazardly created starting populace which is a lot of potential arrangements identified with the issue. In every age of the optimization procedure, the natural administrators are utilized to make next populace by the expectation that the new populace will be better the former one. The primary administrators utilized in this algorithm are choice, encoding, hybrid and transformations. The new arrangements are chosen from the present populaces as per their worth wellness capacities (Table1). Concordance search was right off the bat proposed in the exposition by Geem [19], at that point

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introduced in a diary paper by the Geem et al. [2]. It is gotten from a counterfeit marvel found in melodic execution in particular the way toward looking for better amicability. Melodic exhibitions look for a best state dictated by tasteful estimation, as the optimization algorithms look for a best state controlled by target work assessment. This algorithm stars an underlying congruity memory (arrangements sets) and utilized some parameter, for example, amicability memory thinking about rate (HMCR) to improve the following concordance memory. Counterfeit Bee Colony mimics the keen rummaging conduct of bumble bee swarm. Utilized honey bees, jobless honey bees, and scout honey bees are the kind of honey bee characterized in this algorithm. Utilized honey bees search nourishment around the nourishment source and they store the nectar. Jobless honey bees pick the wellspring of nourishment with certain likelihood by following the moves of the utilized honey bees. The jobless honey bees go to the wellspring of the chose nourishment and start to store nectar as utilized honey bees. Utilized honey bees that devour nourishment sources become scout honey bees to scan for new sources [20]. Particle Swarm Optimization is an optimization technique dependent on the utilizing a populace of particles to locate the ideal arrangement [6,21]. In this algorithm, swarm is comprised of particles which are the people (practical arrangements). This algorithm doesn't require subordinate data and has a simple execution in looking through the ideal arrangements. To discover best position (ideal arrangements) every particle helps out one another by moving as indicated by their speed [22]. Cuckoo Search Algorithm depends on the commit brood parasitic conduct of some cuckoo species in blend with the Levy flight conduct of certain winged animals and organic product flies [9]. There are three standards to actualize this algorithm: each cuckoo lay each egg in turn and dump its egg in haphazardly picked home. The egg in a home speaks to an answer and cuckoo egg speaks to another answer for the procedure of the optimization issue. Like different techniques, the best arrangement (best home) is moved to the following ages. The quantity of accessible host homes is fixed, and the egg laid by a cuckoo is found by the host fledgling with a likelihood. Differential Evolution is a parallel direct hunt [15]. Like the other evolution algorithms, DE utilizes an underlying populace. There are two fundamental parts in the optimization procedure of CA: transformation and hybrid. Through change administrator DE produces new parameter vectors by including the weighted distinction between two populace vectors to a third vector. Parameter blending is called as hybrid. The doable arrangement is created by two segments for the people to come.

2. Formulation of an optimization problem

2.1. Variables to be considered

Parameters picked to depict the structure of a framework are known as the plan factors, which are differed essentially during the advancement procedure. Detailing of streamlining issue starts with recognizing the plan factors. There is no inflexible rule to pick from the earlier the parameters which might be significant in an issue, since one parameter might be progressively significant concerning limiting the expense of the structure, while it might be irrelevant as for augmenting the life of the item. In this way the decision of the significant parameters in a streamlining issue to a great extent relies upon the client. For the most part, cross sectional measurements, thickness and so forth are taken as plan factors. Structure factors are frequently limited, that is, they regularly have most extreme and least qualities. Contingent on the arrangement strategy, these limits can be treated as imperatives. The accompanying contemplations ought to be given in recognizing the structure factors.

- As far as possible the design variables should be independent of each other.
- The number of design variables required to formulate the design problem should be minimum.
- At the initial formulation stage, it is good to have more number of independent parameters as design variables. Later on some of the design variables can be given a fixed value.

2.2. Constraints

The constraints speak to some utilitarian connections among the plan factors and other structure parameters fulfilling certain physical wonder and certain asset confinements. The requirements are essentially three sorts:

- Inequality constraints
- Equality constraints
- Side constraints

2.2.1. Inequality constraints

On the off chance that the functional relationships among the design variables are either more noteworthy than, littler than, or equivalent to, an asset esteem, they are called as imbalance limitations. In this way these limitations guarantee wellbeing against a disappointment mode or good conduct under the given stacking conditions.

2.2.2. Equality constraints

The conditions that ought to precisely coordinate with the asset esteem for the plan to be worthy are equity constraints.

2.2.3. Side constraints

The constraints, for example, most extreme and least estimation of design variables are side constraints. They force geometric confinements on the design variables.

2.3. Objective function

There will be more than one feasible answer for a large portion of the building designs and the point of enhancement is to choose the best one among the feasible designs. In this way a paradigm must be planned for choosing the best one out of the feasible solutions. The standard must be a scalar capacity of the design variables whose numerical worth can be gotten once the design is indicated. Such a foundation is known as the target capacity of the streamlining issue.

3. Optimization methods for civil engineering applications

Different optimization techniques are accessible that can be effectively used to decide the ideal qualities. These techniques can be characterized in to two gatherings: Gradient and Direct search strategies (Non gradient techniques).

Gradient based strategies utilize calculus and subsidiaries of the target capacity and requirements to scan for the ideal. By and large, the strategies for optimization which require gradient data are viewed as increasingly productive. (Krishnamoorthy, [1]). During the procedure of optimization of the structure factors, the imperatives set on the arrangement should likewise be considered. There are different techniques that can be utilized to decide the ideal arrangement of structure factors that can give the base or most extreme incentive for a particular capacity. Of these strategies, there are two essential methods for deciding the ideal worth, utilizing a differential strategy or search technique in the structure field. These two techniques can be additionally separated in to

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two sub bunches as, issues with requirements and without imperatives. For issues without imperatives, the differential calculus technique is considered as the best methods for accomplishing an ideal arrangement. For issues with imperatives there is a decision between differential calculus strategies (Lagrange & Kuhn-Tucker) or search techniques (Linear Programming and Integer-Linear Programming) (Querin, [2]). Non-gradient based methods utilise just function esteems at various focuses are utilized to play out a hunt and don't utilize the partial derivatives of the function and thus are called non - gradient strategies. These strategies are generally appropriate for straightforward issues including a moderately modest number of factors. (Rao, [3])

4. Previous Literature on optimization methods for geotechnical applications

Pei and Xia [26] exhibited an examination on the structure of fortified cantilever holding dividers utilizing heuristic optimization algorithms which are the genetic algorithm (GA), particle swarm optimization (PSO) and reenacted toughening (SA). The limitations of this optimization issue are the plan necessities and geometrical requirements. To complete the optimization procedure 25 imperatives are set up, and 9 parameters are chosen by the creators. The target capacity of the issue is the cost capacity of the cantilever holding divider including the expense of cement and fortification per direct meter. This examination was recently exhibited in the International Conference on Structural Computation and Geo spacialized Mechanics in 2012. Yepes et al. [24] exhibited a parametric report on optimization of earth-holding dividers. They utilized SA algorithm to enhance the dividers from 4 to 10 m in tallness for various fills and bearing conditions. The structure factors of their concern are the geometrical properties of the divider, material sorts and the fortification set-up. The cost capacity is considered as the goal work. In the auxiliary investigation of the divider toppling, sliding and ground stresses are considered as basic point of confinement. Their examination assesses the general significance of elements, for example, the constraint of kerb avoidances and base contact coefficient. Toward the finish of their investigation, the creators revealed the upper bound of 50 kg/m3 of support in the kerb and 60 kg/m3 for the general divider. Atabay [25] utilized the GA to enhance 3D-dimensional beamless fortified solid shear-divider frameworks. In this examination, the all-out material cost work is utilized as the target capacity and limitations of auxiliary optimization issue are considered by the necessities of the fortification solid determination (TS500) and the seismic code of Turkey which is placed into impact on 1998. Basic framework is broke down by GENOPT which was created by the creator. By utilizing this program, 13-amazed beamless structure was enhanced. In the finish of the investigation, the creator expressed that the GENOPT not just substantial for the cost optimization of shear-divider fortified solid structure sys yet additionally is legitimate for the many strengthened solid structure frameworks.

Hosseinzadeh and Joosse [27] revealed the structure optimization of the holding dividers in slender channels. The creators built up an ecologically cordial strategy for financial plan and optimization of holding divider. Their examination incorporates both expository and numerical techniques. To explore the conduct of covering uninvolved zones and its effect on the detached soil obstruction limit are the primary motivation behind this investigation. In the limited component examination, the Plaxis program is favored by the creators. The creator is likewise completed the affectability investigations as for endorsed removal, interface geometry, soil/divider rubbing, work refinement, limit conditions, emptying reloading Poisson's proportion and soil solidness. Toward the finish of their investigation, the creators bring up that the created model can be utilized as reference for repeating the outcomes for homogeneous soil layering in completely depleted conditions. Sadoglu [28] analyzed the structure optimization of balanced gravity holding dividers. The plan of the divider was conveyed by the Building Code Requirements for Structural Concrete (ACI 318-99). To lessen the expenses of the complete divider, the cross-areas territory of the divider is chosen as a target work by the creator. The issue is fathomed by creating PC program-based inside point technique. The imperative of this optimization issue are plan requirements, twisting check limitations, bearing limit imperative, shear confirmation imperatives, absolute vertical powers inside the center third of the base limitation, sliding limitation and the toppling requirement. Khajehzadeh et al. [29] introduced an investigation on the monetary plan of holding divider utilizing particle swarm optimization with detached assemblage. The writers built up a PC program in MATLAB utilizing PSOPC (particle swarm optimization with detached gathering which was proposed initially by He et al. [30]). This program is just required to bolster the information parameters like soil and material properties and security factors. They utilized the expense of the holding divider as a target work and considered the punishment work strategy to applying the requirements which are the geotechnical and basic structure limits. The expense of the all-out divider comprises of the unit cost of solid, removal, refill, formwork, and support. Das et al. [31] utilized the elitist non-commanded arranging genetic algorithm (NSGA-II) for the ideal structure of holding divider. They considered both expense and the factor of wellbeing simultaneously in the optimization procedure of the divider and completed the multi-target optimization approach. Along these lines, they got of compelling Pareto ideal arrangements rather than a solitary arrangement. The basic strength is the imperative of the optimization procedure for this examination. The creators got both appropriate FOS and the relating cost the comparing balance measurements and level of support. Gandomi et al. [32] introduced an examination by utilizing some detest optimization methods: These are the quickened particle swarm optimization (APSO), firefly algorithm (FA), and cuckoo search (CS). The creators planned to streamline the cantilever retaining wall dependent on the ACI 318–05 strategy. The plan factors are persistent for wall geometry and discrete for steel reinforcement. The toppling, sliding, and bearing limit disappointment modes are the geometrical limitation and the shear and minute disappointment at the stem, heel, toe, and shear key are the basic structure requirement of the optimization issue. Sable and Archana [33] utilized the "optimtool" in MATLAB to locate the base expense and weight for concrete retaining walls. The upsetting, sliding, and bearing pressure are the requirement of the issue. The creators sorted to the plan factors in two gatherings: geometric components of wall cross-area and steel reinforcement. Geometric plan factors can be consistent or discrete qualities. In any case, steel reinforcement factors are discrete. Sheikholeslami et al. [34] consolidated the firefly algorithm (FA) and harmony search (HS) procedure (IFA–HS) to take care of plan issues of reinforced concrete retaining walls. In this new procedure, the HS operators are incorporated into the FA. The creators utilized the IFA–HS to enhance the reinforced concrete retaining walls. The expenses of concrete and steel reinforcement are considered as a goal work. Factor of security, dependability, and material properties of the wall are the limitations of the optimization issue completed by the creators. Toward the finish of the examination, the creators presumed that the IFA–HS algorithm was both computationally effective and fit for producing least–cost retaining wall structures. Jasim and Al-Yaqoobi [36] made an investigation on Optimum Design of Tied Back Retaining Wall. The creators utilized the GA in the optimtool of Matlab to plan the wall. The plan factors of this investigation are the geometric measurements and the measures of reinforcement. The bending moment and shear

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force limits, and a portion of different measures are considered the imperative of the issue. Toward the finish of the investigation, the creators reasoned that the expansion of the suitable worry of bind steel prompts the decline of the base expense.

5. Transportation engineering related optimization tools

5.1. Genetic algorithm

Genetic algorithms have been created by John Holland at the University of Michigan. (Goldberg, [9]) Genetic algorithms are automated hunt and streamlining algorithms dependent on the mechanics of characteristic choice and normal genetics. They join natural selection among string structures and a deliberate data trade guided by arbitrary operators to frame a reasonable hunt system. Genetic algorithms start with an arbitrarily made population of string structures. Each string is then assessed. To make better population, the arbitrary population is worked by three operators – reproduction, cross over and change. The reproduction operator chooses great strings in a population and structures the mating pool. The cross over operator chooses two strings from the mating pool aimlessly and trades some segment of the strings. The third operator transformation changes the string locally to make a superior string with a little likelihood. At that point the population is assessed and tried for termination. The population is over and over worked by these operators till the termination criteria are achieved. The fundamental theorem of the genetic algorithm was developed by Holland. GA was used to optimize the FRP composite plate as shown in Fig. 3 and the objective was minimizing the weight and the cost of FRP plate. Two types of external loads were applied; impact load and static load. It was found that the optimization of composite structure using parallel GA gives relatively a good convergence and low process time. In addition, it was found that the quality of the results depends on the problem size. He and Aref used GA to find the optimum selection of design parameters; the number of stiffeners, thicknesses, and the orientations of outer skin layers of the fibre composite bridge deck, as shown in Fig. 8. They concluded that the weight was decreased by 25% from the initial design, and the GA algorithm might be the suitable method to deal with this type of problems because it can accommodate both discrete and continuous design variables. Kim et al. studied the optimum shape of hollow pultrusion fibre composite deck bridge under the truck load DB-24. The objective function was the cost minimization, and the conclusion was made that the trapezoidal shape was the optimum shape for hollow bridge deck as shown in. It showed that the sensitivity of deflection and buckling to the deck dimensions was higher than the material variables. However, the estimated cost of the optimized GFRP deck is twice compared to the conventional concrete deck. Cai and Aref [45] expressed some specialized bulky coming about because of expanding range of cable-stayed bridges and utilizing customary materials have not delivered agreeably results to mitigate these specialized difficulties. They built up a GA-based optimization technique to adapt to this issue. The proposed technique had the option to locate the ideal circulation of fibre reinforced polymeric composites for the deck and cable arrangement of cable-stayed spans. Numerical examinations indicated that ideal mix of hybrid glass FRP-concrete deck and carbon FRP-steel cable frameworks offers 33 and 12% execution enhancement for the static and streamlined conduct of cable-stayed spans. Cai and Aref [46] tended to utilization of carbon fibre reinforced polymeric (CFRP) materials as an option in contrast to the conventional materials for long-length cable-stayed spans. As in [45], they likewise actualized a GA-based optimization system to discover ideal mix of CFRP composites with steel.

Liu and Chang [49] exhibited a GA-based arrangement methodology to upgrade a blood vessel signal issue. As per the traffic designs got from the finish of the optimization system, one of two options demonstrating as either limiting the all-out movement time or boosting the absolute throughput over the objective zone for the control goal can be picked. Exploratory investigations completed a model blood vessel of four crossing points by utilizing the GA-based arrangement approach showed its viability in structure of blood vessel signals, particularly under clogged, popularity traffic conditions. Silva et al. [48] tended to the significance of the

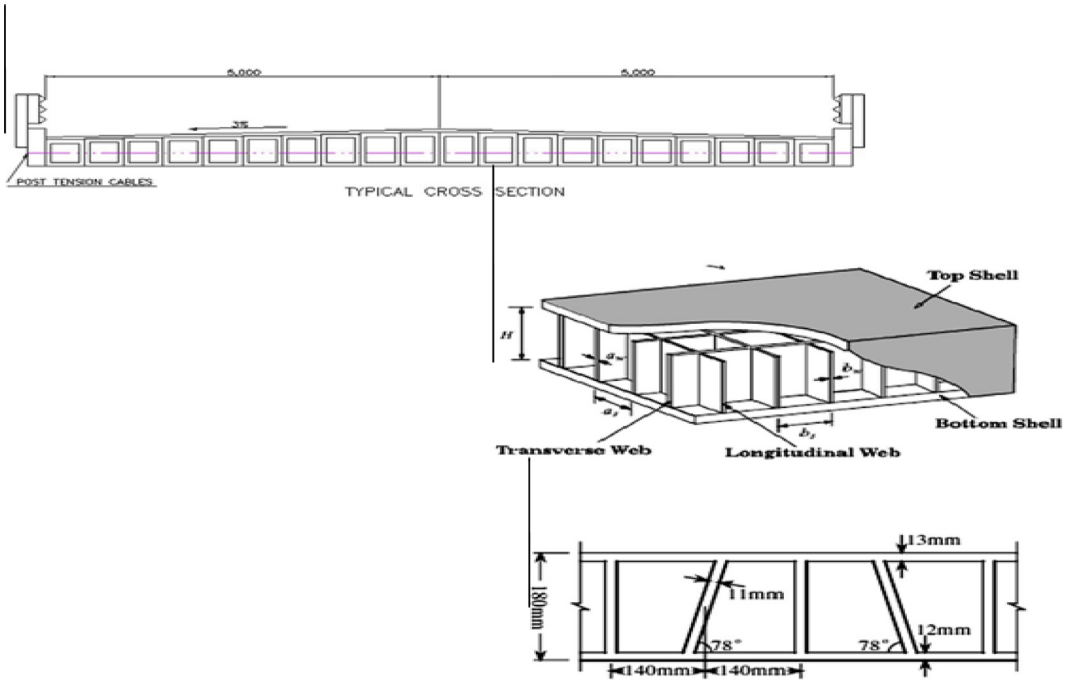

Fig. 3. Bridge and FRP composite decks cross-sectional elements considered for GA optimization by previous studies (Awad et al., 2011).

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ecological and operational consequences for the structures, which bring about some disintegration of structures. They proposed a novel harm location strategy dependent on solo and nonparametric GA to indicate the harm in spans emerging from the nearness of natural and operational impacts. The GA was likewise fortified by a novel concentric hyper circle algorithm. The capacities of the strategy were researched on the basic harm identification procedure of two edges: Z-24 Bridge and Tamar Bridge. Discoveries demonstrated the strength and viability of the proposed approach on recognizing the harm on connect framework. Hu and Liu [50] proposed balance optimization model dependent on GA and target of which was to limit complete deferral for the primary facilitated bearing and to think about the exhibition of the other way simultaneously. The proposed system was inspected on a fundamental blood vessel (TH55) in Minnesota, and it had the option to accomplish diminishing the movement deferral of composed course essentially without trading off the exhibition of the contrary methodology.

5.2. Other optimization techniques in solving real-life transportation problems

Marti et al. [38] portrayed a technique to acquire the financial expense of pre-focused on concrete precast street spans. Their algorithm utilized a variation of SA as a solver. Optimization issue of two fold U-turn median openings and *iso*-static ranges spans was depicted with 59 discrete structure factors including the geometry of the shaft and the piece, materials in the two components, just as dynamic and inactive reinforcement. Contingent upon the outcomes got in [38], it was communicated that distinctive financial situations for steel and concrete costs influence the properties of the expense upgraded spans. Carbonell et al. [39] took care of cost minimization issue of reinforced concrete vaults in street development. Three heuristic optimization techniques were actualized to lead optimization process. One of three techniques is SA. For the optimization issue, the expense of the vaults was taken as target work while 49 discrete plan factors were considered. Applying the three optimization algorithms, 10% cost sparing was acquired for the vault of 12.40 m of flat free range, 3.00 m of vertical tallness of the sidelong walls and 1.00 m of earth spread concerning its customary plan. Among the applied optimization algorithms, SA beat over others regarding best outcomes. Putha et al. [37] applied ACO algorithm to illuminate the over-immersed network traffic signal coordination issue. They distinguished planning techniques of two model network utilizing the proposed algorithm. One of two models networks analyzed in [37] was taken from the specialized writing while other was a real traffic network model of the City of Fort Worth traffic signal network. What's more, the got outcomes were contrasted and the past examinations which were utilized GA to take care of the oversaturated signal coordination issue. At long last, it was reasoned that for the higher number of model executions, ACO become a decent choice to take care of the issue of signal coordination for oversaturated traffic networks. Stevanovic et al. [42] tended to the significance of decreasing extreme fuel consumption and vehicular emanation on urban lanes. To deal with this issue customarily signal timing is enhanced. They proposed a device dependent on incorporating of three recently created apparatuses called as VISSIM, CMEM, and VISGAOST to enhance signal timings and limiting fuel consumption and CO2 outflow. A 14-crossing point network in Park City, Utah was considered as a contextual investigation and two significant goals; I) correlation of evaluated of the fuel consumption, and ii) limit vehicular outflows were mulled over for the VISGAOST optimization of signal timing. Narayanan and Suribabu [53] utilized DE algorithm to arrive at an answer among the difficult options of time, cost and quality for development venture. The proposed approach was executed for two multi-target time–cost-quality issues. Initial one comprises of seven while other 18 development exercises. Contrasting and existing ones, the displayed approach had the option to create best ideal answer for development multi-target optimization issues that limit time and cost of the tasks while expanding quality. Elbeltagi et al. [55] expected to advance a venture planning issue including all structure criteria, for example, time, cost, asset, and income. For this reason, they built up multi-objectives in general optimization model dependent on PSO for venture booking issue. The model was amended on venture separated in to 24 significant exercises. Numerical examinations did for a genuine contextual analysis development model exhibited that multi-objective PSO procedure had the option to deliver results every one of all offers palatable elective answer for multi-objective optimization of development ventures. Bettemir and Birgönül [56] talked about favourable position and detriments of heuristic, *meta*-heuristic algorithms and careful technique utilized for taking care of time–cost exchange off issue. They proposed a network examination algorithm dependent on least cost-slant idea to improve discrete time–cost exchange off issue. The network examination algorithm was analyzed on 18 and 63 movement ventures, and it was inferred that computational interest of the proposed way to deal with locate the ideal or close ideal arrangement is altogether lower than the *meta*-heuristic algorithms. Choddousi et al. [65] tended to intercompabilities of the cost and duration of the exercises and distributed assets and asset levelling. Subsequently, they together received the issues known as asset compelled venture booking issue, discrete time–cost exchange off issue, and asset assignment and asset levelling issue in their optimization model. Use of the model showed that model gives increasingly useful arrangements as far as asset distribution and levelling. Tavana et al. [66] proposed another multi-objective multi-mode model for tackling discrete time–cost-quality exchange off issues with acquisition and summed up priority relations. Including of acquisition and summed up priority relations in venture booking issues made the issue explored progressively proper with genuine tasks. Zamarrón-Mieza et al. [67] as of late inspected the utilization of multi-criteria choice investigation for maturing dam the board. Multi-Attribute Decision Making procedures had a significant nearness under the single methodology, particularly the Analytic Hierarchy Process, and its mix with Technique for Order of Preference by Similarity to Ideal Solution was conspicuous under the hybrid methodology; while a high assortment of reciprocal strategies was recognized. A developing hybridization and fuzzification are the two most pertinent patterns watched. The incorporation of partners inside the basic leadership process and the consideration of exchange offs and interactions between segments inside the assessment model must get a more profound investigation. In spite of the dynamic combination of Multi-Criteria Decision Making in dam the executives, further research is required to separate among level headed and instinctive choice procedures. Furthermore, the need to address benefits, openings, costs and dangers identified with fix, overhauling or expulsion quantifies in maturing dams recommends the Analytic Network Process, not yet investigated under this methodology, as an interesting way worth exploring. Penadés-Plà et al. [68] analyses 77 diary articles of multi-criteria basic leadership strategies at every life-cycle period of an extension, from structure to reusing or destruction. This examination indicated the utilization of various techniques in the basic leadership periods of supportable extensions. Moreover, the contrasts between multi-quality and multi-objective basic leadership were clarified, indicating instances of multi-objective basic leadership. The criteria and techniques applied to every life-cycle stage, as depicted by the creators, are shown. At last, a factual report was completed to show drifts between the strategies and the life-cycle stages.

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6. Optimization applications in materials design

Apalak et al. [99] exhibited an investigation identified with the optimization of the laminated composite plates. They expected to discover greatest basic recurrence for composite plates utilizing genetic algorithm (GA). The limited component method is utilized in the count of the key recurrence of the composite plates. The tool stash of the MATLAB writing computer programs was favoured by the writers to discover most extreme first recurrence estimation of the laminated composite plates. The creators utilized the fake neural network to diminish the tedious which is important to deal with limited component strategy to figure recurrence of the model. That is, the neural network model is utilized as an option numerical investigation for figuring of the recurrence. Koide et al. [100] upgraded the laminated composite plate utilizing insect settlement algorithm (ACO). To exhibit the proficiency of their program, the creators tried the created algorithm on the four numerical models. The structure variables utilized in this investigation are the direction of the fibre and he material. Cost of the material is chosen as an objective capacity for the created algorithm. Greatest load of the structure and the clasping are the restrictions of the optimization issue. The created program based on the ACO indicated a phenomenal performance. In the numerical model, the creators considered distinctive sort of mechanical issue. The same number of researchers, the creators utilized the MATLAB to build up their algorithm. Honda et al. [101] played out a discrete optimization for composite plates. The common frequencies of the composite layers are the objective capacity of the optimization algorithm. They characterized the best arrangement of the overlay details utilizing angle strategy. As opposed to past researchers utilizing the genetic algorithm, the creators of this paper built up a basic procedure. By utilizing diverse limit in numerical models, the right ideal arrangements can be gotten with this created algorithm. Topal et al. [102] made an investigation on the stacking succession optimization by utilizing Teaching–Learning-Based Optimization algorithm. The creators additionally utilized the other optimization algorithms system named Artificial Bee Colony (ABC). In the optimization procedure the most extreme number of emphasis and the populace size are 100 and 30, separately. The fibre point of each layer is the plan variables of the zone parcels of the proposed algorithms. The essential recurrence of the laminated layer is the objective capacity of the program. The constraints are not considered, that is, this issue can be classified as an unconstrained optimization issue. Yusup et al. [109] tended to that cutting rate, profundity of cut and outspread rake edge are ordinarily embraced parameters as plan variables in the optimization of machining process. They likewise expressed that to take care of this sort of optimization issue by and large *meta*-heuristic algorithms were used. They investigated the utilization of Particle Swarm Optimization (PSO) on those issues identified with the machining procedure, which were examined by the researchers from 2007 to 2011. Based on the audit procedure, they contended that the optimization of machining process took care of with PSO is generally connected with the multi-pass turning. Then again, they additionally communicated that the machining performance generally received are the generation costs. Apalak et al. [110] applied Artificial Bee Colony (ABC) algorithm as a streamlining agent in layer optimization of balanced laminated composite plates. The issue was analyzed under various limit condition plans, and the principle reason for this optimization procedure was to boost the primary regular recurrence of the relating plates framework. To satisfy this undertaking the limited component strategy was utilized to recognize the main normal recurrence of the laminated composite plates under shifting stacking arrangements. For the examined issue, the outcomes got by utilizing ABC algorithm for the ideal stacking arrangements showed that those were additionally significant when contrasting and the outcomes acquired by actualizing the genetic algorithm incorporated with the limited component technique. Karaya and Soykasap [142] highlighted some wonderful highlights of the composites and why the clients use these materials in the plan of particular structures, for example, airplane, rocket, marine vessels and so on. They proposed a hybridization plan to improve the material properties of the composites. Two hybridization conspire, carbon/epoxy and glass/epoxy hybrid utilizes, were applied. The impact of these hybrid cover on the expense of composite plates were explored by utilizing two distinctive *meta*-heuristic optimization algorithms, GA and SA. Because of numerical examinations, they expressed that both optimization algorithms actualized were fit for finding the ideal stacking successions of hybrid composite plates subject to boost of characteristic frequencies and clasping load. In any case, it was likewise sketched out that the general performance of GA was superior to SA.

7. Optimization applications in structure design

Dede & Ayvaz [83] studied the optimization of plane and space trusses with a Teaching-learning- based optimization (TLBO). Cross-sectional areas of bars and nodal coordinates were considered as the design variables. The method was applied to five structures. When compared to results obtained by other studies, it was concluded by the authors that the algorithm can be effectively used to design truss structures. Cicconi et al. [80] contemplated a system to decrease the weight and the expense of enormous steel structures during the early plan stage. A stage instrument was created to help the programmed optimization of steel outlines utilizing genetic algorithms and SAP2000 programming. An experiment picked was an oil and gas module of a current coastal force plant. Two distinct investigations were proposed: the first were centered around weight minimization and respected uniquely to static stacking, while the second thought to be three stacking cases (static, load transport and ocean transport). Utilizing the proposed optimization technique, the mass was decreased somewhere in the range of 5% and 15%. Medeiros and Kripka [81] applied optimization to limit the expense of reinforced concrete shafts so as to propose pre-measuring parameters. The cross-sectional tallness of each gathering of bars was taken as plan factors. The constraints were identified with flexural, shearing, torsion, web reinforcements and functionality limit states. An optimization programming was created by the relationship of grillage examination and mimicked toughening optimization technique. The impact of relative expense of steel, concrete and formwork on all out expense was additionally examined. As per creators, reenacted tempering heuristic was effective in limiting structure costs, and the product can be a significant device for the pre-measuring of building floor frameworks and furthermore for singular pillars. Jalili and Hosseinzadeh [79] utilized Culture Algorithm to get least weight of brackets under stress and deflection constraints. Cross sectional region of every part was taken as the structure factors. So as to test the exhibition of the technique, four supports were broke down. The got outcomes demonstrated the productivity of the strategy in finding the ideal plan, acquiring. When contrasted with other old style strategies, Culture Algorithm led to lighter auxiliary loads with less basic investigations. Kaveh and Talatahari [82] consolidated a variation of Particle Swarm with Ant Colony and Harmony Search strategies into another technique named discrete heuristic particle swarm subterranean insect state optimization (DHPSACO). This technique was then utilized to discrete optimization of supports. Four structures are tried to so as to confirm the proficiency

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of the proposed strategy. As indicated by creators, better arrangements were acquired contrasted with other old style algorithms. These arrangements were acquired with less computational time and fast of union. Pholdee & Bureerat [84] compared the performance of 24 meta- heuristic methods for truss optimization with dynamic constraints. Established methods were used to minimize mass of five different trusses. Based on a statistic analysis, the authors concluded that the best performance optimizers were evolution strategy with covariance matrix adaptation and differential evolution. Alapati [85] used genetic algorithm (GA) to weight minimization of plane trusses. The stresses and deflections were considered as the constraints of the problem. The method was applied to a classical benchmark structure (ten-bar truss). Some conclusions regarding GA parameters were presented. Chowdhury et al. [86] modeled plain concrete and steel fiber reinforced concrete (SFRC) cylinder specimens numerically, with experimental validation. The experimental study evaluated the increase in capacity of cylinders of stone and brick concrete and SFRC. The numerical study aimed to optimize the main controlling parameters to model concrete and SFRC in finite element platform. The final results presented a good correlation among numerical and experimental results. Farshchin et al. [87] introduced a multi-class teaching–learning-based optimization technique (MC-TLBO) to structures optimization with frequency constraints. The algorithm was tested with several truss structures, and the results were compared to those obtained with a modified TLBO algorithm and with other methods. The results indicated that the method can lead to low cost designs. In addition, a statistic analysis indicated that MC-TLBO was more robust and efficient than other studied techniques. Talaslioglu [88] minimized weight and joint displacements of grid structures, being the constraints related to serviceability and ultimate strength. Four Multi-objective optimization algorithms were applied to three examples and compared using different combinations of optimizer related parameters. To the examples analyzed, Adapting Scatter Search showed the best performance. Poitras et al. [89] adopted Particle swarm optimization (PSO) for the minimum mass or cost design of composite and non-composite steel floor systems. The design variables were the size of girders and secondary beams, as well as the stud spacing and the concrete thickness. The performance of the algorithm was tested for three floor configurations. According to authors, PSO algorithm achieved the optimal results to all examples. Dede [90] used Teaching–Learning-Based Optimization algorithm (TLBO) for the minimum weight design of grillage systems. The design variables were the cross-sectional areas of W-shapes, considered as discrete variables. Several structures were optimized aiming to investigate the efficiency of the algorithm. The results were compared with those obtained from previous studies. According to the results, TLBO algorithm outperformed the other algorithms. Kaveh & Bakhshpoori [91] presented the application of the Cuckoo Search (CS) to weight minimization of truss structures, considering both discrete and continuous design variables. In order to investigate the performance of the algorithm, three examples were presented, consisting of two space trusses and a dome-shaped truss. The results, presented in terms of results and number of function evaluations, indicated the robustness of the algorithm. Hasançebi et al [92] compared the performance of seven techniques in optimum design of truss structures. First, a verification of the algorithms used to implement the techniques was carried out using a benchmark problem. Next, the techniques were compared in terms of solution accuracies, convergence rates and reliabilities using four real size design examples formulated according to the design limitations imposed by ASD-AISC. To the examples considered, the results revealed that simulated annealing and evolution strategies presented the best performance. Torres-Machi et al. [95] streamlined the structure of high-performance concrete for reinforced concrete shafts, utilizing three hybrid optimization systems: Variable Neighborhood Descent (VND), Reduced Neighborhood Search (RNS) and Basic Variable Neighborhood Search (BVNS). The algorithms were applied to least cost and least implanted carbon dioxide outflows. The outcomes demonstrated that the objective capacity, both to financial and biological shafts, increments allegorically with the range length. Sharafi et al. [93] presented a procedure for the shape and sizing optimization of open and closed thin-walled steel sections using the graph theory. A multi-objective optimization problem aimed to minimize the mass and maximize the strength of the section. The problems were solved by the usage of multi-colony ant algorithms, and the Pareto-optimal set was obtained. The results showed the applicability of the proposed procedure to shape optimizations of steel sections and sizing optimization roof sheeting. Fabeane et al. [94] examined the optimization of composite bridges, meaning to lessen the expense of scaffold cross segment by shifting the elements of the steel supports. The detail utilized in the investigation and plan of the braces was the AASHTO, and the cases contemplated were straightforward range bridges with various ranges and a variable number of steel supports. The outcomes acquired empowered the recognizable proof of parameters to upgrade plan of composite bridges, indicating that the utilization of criteria based on optimization procedures can prompt a critical decrease in the expense of the structures.

8. Conclusions

Different optimization and solution methods are examined in this audit. A large portion of these conventional algorithms end when the inclination of the target work is near zero. They don't ensure to discover global ideal solutions. In the greater part of the genuine designing issues, a few reenactments are required to assess the goal work. Along these lines precise assessment of the inclination may not be conceivable in certain issues. This proposes to take care of discrete or broken issues, some powerful hunt algorithms, for example, genetic algorithm is required. They work with a coding of factors which discreteness the hunt space despite the fact that the capacity is consistent. They process more than one string at the same time and the solution will be a global optimum. Genetic algorithms grant the utilization of probabilistic principles likewise to control their inquiry. It is seen that diverse optimization algorithms are utilized for various applications, yet one need not guarantee a specific optimization algorithm as the "best" algorithm among all the optimization algorithms accessible in the writing. Actually, there may not be any such 'best' algorithm existing. A specific algorithm may not be the "best" for a wide range of optimization issues. On the off chance that any algorithm is found having certain restrictions, at that point the endeavors of the researchers ought to be to discover the approaches to conquer the confinements and to additionally reinforce the algorithm. Researchers are urged to make upgrades to the current optimization algorithms or potentially to grow new optimization algorithms.

CRediT authorship contribution statement

Sarvesh P.S. Rajput: Conceptualization, Methodology. **Suprabeet Datta:** Data curation, Writing - original draft, Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

[1] Y. Zhang, S.T. Ng, An ant colony system-based decision support system for construction time-cost optimization, J. Civil Eng. Manage. 18 (4) (2012) 580–589.
[2] H. Zhang, H. Li, Multi-objective particle swarm optimization for construction time-cost tradeoff problems, Constr. Manage. Econom. 28 (1) (2010) 75–88.
[3] Zamarrón-Mieza, V. Yepes, J.M. Moreno-Jiménez, A systematic review of application of multi-criteria decision analysis for aging-dam, J. Cleaner Prod. 147 (2017) 217–230.
[4] N. Yusup, A.M. Zain, S.Z.M. Hashim, Overview of PSO for optimizing process parameters of machining, Procedia Eng. 29 (2012) 914–923.
[5] V. Yepes, J. Alcala, C. Perea, Vidosa F.G. A parametric study of optimum earth-retaining walls by simulated annealing, Eng. Struct. 30 (2008) 821–830.
[6] X.S. Yang, Firefly Algorithm, Stochastic Test Functions and Design Optimisation, Int. J. Bio-Inspired Computation 2 (2) (2010) 78–84.
[7] X.S. Yang, S. Deb Cuckoo search via levy flights, In: Nature & Biologically Inspired Computing, NaBIC, India: 210-214, 2009.
[8] X.S. Yang Nature-Inspired Metaheuristic Algorithms. Luniver Press, United Kingdom, 2008.
[9] C. Xiao, T. Ling, Y. Qiu, Optimization of technical measures for improving high-temperature performance of asphalt–rubber mixture, J. Modern Trans. 21 (4) (2013) 273–280.
[10] M.N.A. Wahab, S.N. Meziani, A Atyabi A Comprehensive Review of Swarm Optimization Algorithms. 1, pp. 1-36, 2015
[11] E. Uzlu, M. Kankal, A. Akpınar, T. Dede, Estimates of energy consumption in Turkey using neural Networks with the teaching learning-based optimization algorithm, Energy 75 (2014) 295–303.
[12] Torres-Machi, V. Yepes, J. Alcalá, E. Pellicer, Optimization of high-performance concrete structures by variable neighborhood search, Int. J. Civil Eng. Trans. A Civ. Eng. 11 (2) (2013) 90–99.
[13] U. Topal, T. Dede, H.T. Öztürk, Stacking sequence optimization for maximum fundamental frequency of simply supported anti-symmetric laminated composite plates using teaching–learning- based optimization, KSCE J. Civ. Eng. 266 (2017) 2281–2288.
[14] V.R. Tonne, P.M. Mohite, Optimization and improvement in stability of counterfort retaining wall with relief shelf, IJRET Int. J. Res. Eng. Technol. 4 (4) (2015) 447–545.
[15] B. Thamaraikannan V. Thirunavukkaras Design Optimization of Mechanical Component Using an Enhanced Teaching-Learning Based Optimization Algorithm with Differential Operator. Mathematical Problems in Engineering, Hindawi Publishing Corporation, pp. 1-10, 2014.
[16] M. Tavana A.R. Abtahi K. Khalili-Damghani, A new multi-objective multi-mode model for solving pre-emptive time–cost–quality trade-off project scheduling problems. Expert Systems with Applications 4, pp. 1830-1846, 2014.
[17] T. Talaslioglu, Multi-objective design optimization of grillage systems according to LRFD-AISC, Adv. Civil Eng. 211 (2011) 1–24.
[18] R. Storn, K. Price, Differential evolution –a simple and efficient heuristic for global optimisation over continuous spaces, J. Global Optim. 11 (1997) 341–359.
[19] Stevanovic J Stevanovic, K. Zhang, S. Batterman, Optimizing traffic control to reduce fuel consumption and vehicular emissions, Transp. Res. Rec. 2128 (2009) 105–113.
[20] S. Srinivasana, S. Ramakrishnan, Multi objective optimization of classification rules using cultural algorithms, Procedia Eng. 30 (2012) 457–465.
[21] S. Singla, S. Gupta, Optimization of reinforced concrete retaining walls of varying heights using relieving platforms, Int. J. Eng. Res. Technol. (IJERT) 4 (6) (2015) 1071–1077.
[22] M. Silva, A. Santos, E. Figueiredo, R. Santos, C. Sales, A novel unsupervised approach based on a genetic algorithm for structural damage detection in bridges, Eng. Appl. Artif. Intell. 52 (2016) 168–180.
[23] M.H. Sadr, H.G. Bargh, Optimization of laminated composite plates for maximum fundamental frequency using Elitist-Genetic algorithm and finite strip method, J. Global Optim. 54 (2012) 707–728.
[24] K.S. Sable, A.P. Archana, Optimization of retaining wall by using optimtool in Matlab, Int. J. Eng. Res. Technol. (IJERT) 1 (6) (2012) 1–11.
[25] S. Sabatino, Dan M Frangopol, Y. Dong, Sustainability-informed maintenance optimization of highway bridges considering multi- attribute utility and risk attitude, Eng. Struct. 102 (8) (2015) 310–321.
[26] M. Rostani, D. Moradinezhad, A. Soufipou, Improved and Competitive Algorithms for Large Scale Multiple Resource-Constrained Project-Scheduling Problems, KSCE J. Civ. Eng. 18 (8) (2014) 1261–1269.
[27] R.G. Reynolds, An introduction to cultural algorithms evolutionary programming. Proc. 3rd Ann. Conf, World Scientific, River Edge, NJ, pp.131–139, 1994.
[28] S.S. Rao, Optimization theory and applications, Wiley Eastern Limited, New Delhi, 1992.
[29] R.V. Rao, D.P. Rai, J. Balic, A multi-objective algorithm for optimization of modern machining processes, Eng. Appl. Artif. Intell. 61 (2017) 103–125.
[30] Rao RV (2016) Chapter 2, Teaching Learning Based Optimization Algorithm. Springer International Publishing Switzerland: 9–39.
[31] R.V. Rao, V.J. Savsani, D.P. Vakharia, Teaching–learning-based optimisation: a novel method for constrained mechanical design optimisation problems, Comput Aided Des 43 (2011) 303–315.
[32] Raissi, S. and R- eslami Farsani, Statistical process optimization through multi response surface methodology, World Acad. Sci. Eng. Technol., 51(5), 2009.
[33] R. Putha, L. Quadrifoglio, E. Zechman, Comparing ant colony optimization and genetic algorithm approaches for solving traffic signal coordination under oversaturation conditions, Comput.-Aided Civ. Infrastruct. Eng. 27 (2012) 14–28.
[34] G. Poitras, G. Lefrançois, Cormier optimization of steel floor systems using particle swarm optimization, J. Constr. Steel Res. 67 (8) (2011) 1225–1231.
[35] Y. Pei, Y. Xia, Design of reinforced cantilever retaining walls using heuristic optimization algorithms, Procedia Earth Planet. Sci. 5 (2012) 32–36.
[36] D.R. Palupi, S.M. Shamsuddin, S.S. Yuhaniz, Particle swarm optimisation: technique, systems and challenges, Int. J. Comput. Appl. 14 (1) (2011).
[37] Osvaldo. M. Querin, Evolutionary Structural Optimization: Stress Based Formulation and Implementation, doctoral diss., Department of Aeronautical Engineering, University of Sydney, Australia, 1997
[38] S.T. Ng, Y. Zhang, Optimizing construction time and cost using ant colony optimization approach, J. Constr. Eng. Manage. 134 (9) (2008) 721–728.
[39] A.S. Narayanan, C.R. Suribabu, Multi-objective optimization of construction project time-cost-quality trade-off using differential evolution algorithm., Jordan J. Civil Eng. 8 (4) (2014) 375–392.
[40] M.S. Morleya, Tricarico C (2014) A comparison of population-based optimization techniques for water distribution system expansion and operation, Procedia Eng. 89 (2014) 13–20.
[41] S. Monghasemi, M.R. Nikoo, M.A.K. Fasaee, A novel multi criteria decision making model for optimizing time–cost–quality trade-off problems in construction projects, Expert Syst. Appl. 42 (2014) 3089–3104.
[42] G.F. Medeiros, M. Kripka, Structural optimization and proposition of pre-sizing parameters for beams in reinforced concrete buildings, Comput. Concrete 11 (3) (2013) 253–270.
[43] F.J. Martinez, F. Gonzalez-Vidosa, A. Hospitaler, J. Alcala, Design of tall bridge piers by ant colony optimization, Eng. Struct. 33 (8) (2011) 2320–2329.
[44] J.V. Marti, F. Gonzalez-Vidosa, V. Yepes, J. Alcala, Design of pre-stressed concrete precast road bridges with hybrid simulated annealing, Eng. Struct. 48 (2013) 342–352.
[45] Y. Liu, G.L. Chang, An arterial signal optimization model for intersections experiencing queue spillback and lane blockage, Transp. Res. Part C 19 (2011) 130–144.
[46] K. Lenin, B.R. Reddy, M.S. Kalavathi, A new charged system search for solving optimal reactive power dispatch problem, Int. J. Comput. 14 (1) (2014) 22–40.
[47] K.N. Krishnanand, D. Ghose, Glow-worm swarm optimization for simultaneous capture of multiple local optima of multimodal functions, Swarm Intell. 3 (2) (2009) 87–124.
[48] Krishnamoorthy, C.S and Rajeev, S, Computer aided design software and analytical tools. Narosa Publishing House, New Delhi. 1991
[49] C. Koo, T. Hong, S. Kim, An integrated multi-objective optimization model for solving the construction time-cost trade-off problem, J. Civil Eng. Manage. 21 (3) (2015) 323–333.
[50] Koide RM, von Z de França G, Luersen M.A. An ant colony algorithm applied to lay-up optimization of laminated composite plates. Latin American Journal of Solids and Structures 10, pp. 491 – 504, 2013.
[51] O. Kisi, Akay B. OzkanC, Modelling discharge–sediment relationship using neural networks with artificial bee colony algorithm, J. Hydrol. 428–429 (2012) 94–103.
[52] Kaveh, Bakhshpoori T. Optimum Design of Space Trusses Using Cuckoo Search Algorithm with Lévy Flights. IJST, Transactions of Civil Engineering, 37, pp. 1-15, 2013.
[53] A. Kaveh, S. Talatahari, Optimal design of skeletal structures via the charged system search algorithm, Struct. Multidiscip. Optim. (2010).
[54] Kashan A.H. League Championship Algorithm: A new algorithm for numerical function optimization. International Conference of Soft Computing and Pattern Recognition: pp. 43-48, 2009.
[55] M. Karbasi, Estimation of classical hydraulic jump length using teaching–learning based optimization algorithm, J Mater Environ Sci 7 (8) (2016) 2947–2954.
[56] Ş. Karakaya, Ö. Soykasap, Natural frequency and buckling optimization of laminated hybrid composite plates using genetic algorithm and simulated annealing, Struct. Multidiscipl. Opt. 43 (2011) 61–72.
[57] D. Karaboga, B. Basturk, A powerful and efficient algorithm for numerical function optimisation: artificial bee colony (ABC) algorithm, J. Global Optim. 39 (2) (2007) 459–471.
[58] D. Karaboğa, Artificial bee colony, Scholarpedia 5 (3) (2010).
[59] N.A. Jasim, A.M. Al-Yaqoobi, Optimum design of tied back retaining, Wall. Open Journal of Civil Engineering 6 (2016) 139–155.
[60] S. Jalili, Y. Hosseinzadeh, A cultural algorithm for optimal design of truss structures, Latin Am. J. Solids Struct. 12 (2015) 1721–1747.
[61] Nasimi R. IraniR, Application of artificial bee colony-based neural network in bottom hole pressure prediction in underbalanced drilling, J. Petrol. Sci. Eng. 78 (2011) 6–12.
[62] H. Hu, Henry X Liu, Arterial offset optimization using archived high-resolution traffic signal data, Transp. Res. Part C 37 (2013) 131–144.
[63] S. Hosseinzadeh, J.F. Joosse, Design optimisation of retaining walls in narrow trenches using both analytical and numerical methods, Comput. Geotech. 69 (2015) 338–351.
[64] Holland J. H. Adaptation in Natural and Artificial System. University of Michigan Press, Ann Arbor, USA, 1975.

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[65] O. Hasançebi, S. Çarbaş, E. Doğan, F. Erdal, M.P. Saka, Performance evaluation of meta-heuristic search techniques in the optimum design of real size pin jointed structures, Comput. Struct. 87 (5–6) (2014) 284–302.
[66] Goldberg, D. E., Genetic algorithms in search, optimization, and machine learning and reading, Massachusetts, Addison- Wesley Publishing company, 1989
[67] Glover F. Tabu Search-Part I. ORSA Journal on Computing, 1(3), pp.190-206, 1989.
[68] Ghanizadeh A.R. An Optimization Model for Design of Asphalt Pavements Based on IHAP Code Number 234. Advances in Civil Engineering, pp.1-8, 2016.
[69] Geem ZW. Optimal cost design of water distribution networks using harmony search. Dissertation, Korea University, South Korea, 2000.
[70] Z.W. Geem, J.H. Kim, G.V. Loganathan, A new heuristic optimization algorithm: harmony search, Simulation 76 (2) (2001) 60–68.
[71] T. Garcia-Segura, V. Yepes, M.F. Dan, Multi-objective design of post-tensioned concrete road bridges using artificial neural networks, Struct. Multidisciplinary Opt. 56 (2017) 139–150.
[72] A.H. Gandomi, A.R. Kashani, D.A. Roke, M. Mousavi, Optimization of retaining wall design using recent swarm intelligence techniques, Eng. Struct. 103 (2015) 72–84.
[73] R. Fletcher, C.M. Reeves, Function minimization by conjugate gradients, The Computer Journal 7 (2) (1964) 149–154.
[74] R. Fletcher, M.J.D. Powell, A rapidly convergent descent method for minimization, Comput. J. 6 (1963) 163–168.
[75] Elbeltagi E, Ammar M, Sanad H, Kassab M. Overall multiobjective optimization of construction projects scheduling using particle swarm. Engineering, Construction and Architectural Management 23(3): 265- 282.
[76] B.J. Eck, E. Arandia, J. Naoum-Sawaya, F. Wirth, A simulation- optimization approach for reducing background leakage in water systems, Procedia Eng. 83 (2014) 59–68.
[77] Dorigo M (1992) Optimization, learning and natural algorithms. PhD Thesis, Dept. of Electronics, Politecnico di Milano, Italy, Europe.
[78] R. Dogra, N. Gupta, Glow-worm swarm optimization technique for optimal power flow, Adv. Electr. Electric Eng. 4 (2) (2014) 155–160.
[79] T. Dede, Optimum design of grillage structures to LRFD-AISC with teaching-learning based optimization, Struct Multidisc Optim 48 (2013) 955–964.
[80] T. Dede, Y. Ayvaz, Combined size and shape optimization of structures with a new meta-heuristic algorithm, Appl. Soft Comput. 28 (2015) 250–258.
[81] Deb, K.. Optimization for Engineering Design Algorithms and Examples. Prentice Hall of India, 1995.
[82] Deb K. Multi-objective optimization using evolutionary algorithms. John Wiley & Sons Ltd, 2001.
[83] Davidon, W.C., Variable Metric Method for minimization, AEC Research Development Report. No. ANL – 599, 1959
[84] Das M.R., Purohit S., Das S,K. Multi-objective Optimization of Reinforced Cement Concrete Retaining Wall. Indian Geotech J 46(4), pp.354-368, 2016.
[85] P. Civicioglu, Backtracking search optimization algorithm for numerical optimization problems, Appl. Math. Comput. 219 (15) (2013) 8121–8144.
[86] P. Cicconi, M. Germani, S. Bondi, A. Zuliani, E. Cagnacci, A Design Methodology to Support the Optimization of Steel Structures, Procedia CIRP 50 (2016) 58–64.
[87] Chowdhury MA, Islam MM, Zahid Z. I. Finite Element Modeling of Compressive and Splitting Tensile Behavior of Plain Concrete and Steel Fiber Reinforced Concrete Cylinder Specimens. Advances in Civil Engineering, pp. 1-11, 2016.
[88] P. Choddousi, E. Eshtehardian, S. Jooybanpor, A. Javanmardi, Multi- mode resource-constrained discrete time–cost-resource optimization in project scheduling using non-dominated sorting genetic algorithm, Autom. Constr. 30 (2013) 216–227.
[89] Z. Chen, H. Cao, K. Ye, H. Zhu, S. Li, Improved Particle Swarm Optimization-Based Form-Finding Method for Suspension Bridge Installation Analysis, J. Comput. Civil Eng. 29 (3) (2015) 1–13.
[90] Carley K.M., Kamneva N.Y., Reminga J., Defence Technical Information Centre, 2004
[91] Carbonell, Gonzalez-Vidosa F, Yepes V. Design of reinforced concrete road vaults by heuristic optimization. Advances in engineering Software 42, pp.151-159, 2011.
[92] V. Camp, Design of space trusses using big bang-big crunch optimization, J. Struct. Eng. 133 (7) (2007) 999–1008.
[93] Cai H, Amjad A Aref (2015) On the design and optimization of hybrid carbon fibre reinforced polymer-steel cable system for cable-stayed bridges. Composites: Part B, 68, pp. 146-152, 2015.
[94] H. Cai, A.A. Amjad, A genetic algorithm-based multi-objective optimization for hybrid fibre reinforced polymeric deck and cable system of cable-stayed bridges, Struct. Multidisciplinary Opt. 52 (2015) 583–594.
[95] Ö.H. Bettemir, Birgönül MT (2017) Network Analysis Algorithm for the Solution of Discrete Time-Cost Trade-off Problem, KSCE J. Civ. Eng. 21 (4) (2016) 1047–1058.
[96] Belevicius R, Jatulis D, Rusakevicius D, Maciunas D. Optimization of Rigidly Supported Guyed Masts. Advances in Civil Engineering pp. 1-9, 2017.
[97] S. Behera, S. Sahoob, B.B. Pati, A review on optimization algorithms and application to wind energy integration to grid, Renew. Sustain. Energy Rev. 48 (2015) 214–227.
[98] A. Bayram, Kankal M UzluE, T. Dede, Modelling stream dissolved oxygen concentration using teaching–learning based optimization algorithm. Environ, Earth Sci 73 (2016) 6565–6576.
[99] G. Barone, Dan M Frangopol, M. Soliman, Optimization of life- cycle maintenance of deteriorating bridges with respect to expected annual system failure rate and expected cumulative cost, J. Struct. Eng. 140 (2) (2014) 1–13.
[100] G.L.S. Babu, B.M. Basha, Optimum design of cantilever retaining walls using target reliability approach, Int. J. Geomech. 8 (4) (2008) 240–252.
[101] G.L.S. Babu, B.M. Basha, Optimum design of cantilever sheet pile walls in sandy soils using inverse reliability approach, Comput. Geotech. 35 (2008) 134–143.
[102] R.F. Aziz, S.M. Hefez, Y.R. Abuel-Magd, Smart optimization for mega construction projects using artificial intelligence, Alexandria Eng. J. 53 (2014) 591–606.
[103] M.N. Azeez, A. Alsaffar, Construction time-cost optimization modelling using ant colony optimization, J. Eng. 20 (1) (2014) 114–131.
[104] S. Atabay, Cost optimization of three-dimensional beamless reinforced concrete shear-wall systems via genetic algorithm, Expert Syst. Appl. 36 (1) (2009) 3555–3561.
[105] M.K. Apalak, M. Yildirim, R. Ekici, Layer optimization for maximum fundamental frequency of laminated composite plates for different edge conditions, Compos. Sci. Technol. 68 (2) (2008) 537–550.
[106] M.K. Apalak, D. Karaboğa, B. Akay, The artificial bee colony algorithm in layer optimization for the maximum fundamental frequency of symmetrical laminated composite plates, Eng. Optim. 46 (3) (2014) 420–437.
[107] S. Aminbakhsh, R. Sönmez, Pareto front particle swarm optimizer for discrete time-cost trade-off problem, J. Comput. Civil Eng. 31 (1) (2017) 1–10.
[108] S. Aminbakhsh, R. Sönmez, Discrete particle swarm optimization method for the large-scale discrete time–cost trade-off problem, Expert Syst. Appl. 51 (2016) 177–185.
[109] M. Alapati, Discrete optimization of truss structure using genetic algorithm, Int. J. Recent Dev. Eng. Technol. 3 (1) (2014) 105–111.
[110] Afshar, Ziaraty AK, Kaveh A, Sharifi F. Non-dominated Archiving Multi-colony Ant Algorithm in Time–Cost Trade-Off Optimization. Journal of Construction Engineering and Management, 135(7), pp. 668-374, 2009.

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