Abstract most complex civil engineering constructions we find

Business, Industries

Abstract Complexstructures such as bridges need proof of performance over the desired lifetime, prior to the beginning constructions stages, as structural failure can beavoided. Among the most complex civil engineering constructions we findcable-stayed bridges, which are the most advanced bridge designs up to thispoint.

Alongside the development of the cable-stayed bridge the finite element method, a method of structural behaviour prediction, has been developed. Theaim of the present project si to find the most adequate model of a cable-stayedbridge that can be compared, in terms of its structural system, with thecable-stayed bridge located within the Basarab Overpass, Bucharest, Romania. This thesis will be conducting two-dimensional finite element analysis with theaid of Oasys GSA software, as well as a three-dimensional finite element analysiswith the aid of ANSYS Structures software and MIDAS Civil software. Acomparison between the two-dimensional and the three-dimensional models will beconducted, with the consideration of variable materials and element sizes. Thisstudy will respect the structural system present in the Basarab Overpass'cable-stayed bridge. Following theoutcome of the analysis described above, the finale design model will becompared to the real life bridge in order to determine if material costs couldhave been diminished. Introduction Today, one of the most important parts of the CivilEngineering industry is based on the design and analysis stages of a project.

With the development of technology and the construction field, more and morecomplex structures are made; construction that are based on complex geometricalshapes and concepts as well as ingenious materials combinations. These complexconstructions (e. g. cable-stayed bridges) involve a huge increase in terms of manpower, technical expertise, tools, machines and most importantly cost. Therefore, any miscalculation, wrong use of materials or perplexity of the construction phases can concludewith a structural failure of the construction. Those types of mistakes haveconsequences, both time and money wise, which are unacceptable and can, lead toproject failure. On top of that, structures such as dams, nuclear power plants, refineries are of immense concern.

Failure of such structures would havedisastrous outcomes. To make sure such catastrophes don’t occur, preventionmeasures may be taken before even starting the construction process. To ensuremore accurate structures, analysis and modelling tools have been created inorder to foreseen failure scenarios, diminish errors and choose best fittingmaterials before construction starts. The modelling and analytical tools arerequired to ensure the best suiting design outcome for the wanted lifetime ofthe structure at hand. Nonetheless, modelling and analysing help diminish timeand costs in the eventuality of unforeseen design changes.

Since the introduction of the structural analysis, thisstage has seen multiple changes in method and application. Rudimentalstructural analysis includes methods such as moment distribution method, jointmethod, elasticity method which have had immense contributions to the engineeringindustry. Although, the technological advancement enabled the creation ofpowerful electronic computational devices have lead to more complex analyticalmethods.

Today, two of the most frequent and efficient structuralanalysis methods are the numerical method and matrix method; methods thatinvolve a high degree of accuracy. The most commune analytical tool is theFinite Element Analysis. The matrix method is rather similar to the numericalmethod, such that it is based on the use of matrices; only that it is used to analysestructures that involve more complex elements (e. g. frameworks). With the aimof the finite element analysis, a mathematical model is created; model thatsimulates the real life behaviour of the structure analysed. The FEA wouldexamine the non-linear behaviour, the dynamic response and stability of thestructure. In order for the FEA model tohave such high accuracy, various material and geometrical parameters are takeninto account.

Literature Review Finite element analysis of cable-stayed bridges (Kajita T., Cheung Y. K. 1973) presents the analysis of a cable stayed bridge in which thedeck is divided into shall elements an treated as a three dimensional system. In terms of the stayed-cables, are assumed to behave as springs. Construction and Design of Cable-Stayed Bridges (Walter Podolny, Jr.

, Ph. D. and John B. Scalri, Sc. D.) presents the technical attributes ofcable-stayed bridges along side of the construction requirements and stages implied by such s structure. Finite Element Procedures (Klaus-Jurgen

Bathe, 2014) consistsof theoretical information describing the implementation and use of finite elementanalysis.

It presents a vast number of techniques that help the implementationof the finite element method. Dead Load Analysis of Cable-Stayed Bridges (Tao. Zhanfand ZhiMin Wu.

, 2011) describes an optimization method of varied load with theaim of approximating the forces present within the cables, in order to achievethe ideal state. Consequently, theidealized cable forces are used to perform the construction stage analysis. Comparison between three types of cable-stayed bridgesusing structual optimization (Olaf Sarhang Zadeh, 2012) analyses the behaviourof stayed-cables, using finite element analysis, in order to achieve theoptimal design in terms of material use.

Finite Element Analysis The finite element analysis is a numerical method and isa branch of solid mechanics and it is used for solving multi-physics problems. Thismethod of analysis has applications in fields such as: structural analysis, fluiddynamics, thermal analysis or solid mechanics. The main area of application for finite element analysis(FEA) is the linear analysis of solid structures. It is also recognized as thefirst FEA application and it is also the base point of the finite elementmethod (FEM). The standard interpretation for a finite element analysis solutionof solids is known as the displacement method. FEA has been introduced as a method of finding the approximatesolution for problems with an indefinite number of equations and unknownvariables; problems that would be virtually impossible to solve.

The FEM tries to approximate the outcomes ofthe analysed body by dividing the body into smaller segments with virtually thesame properties; this is done using a mesh to delimitate the boundaries of thedivisions. Consequently, the properties calculated gathered from the smallsections are extrapolated onto the whole analysed body. In order to solve complex structures that aredependent of an indefinite number of variables the aid of big computational is necessary. Hence, FEA of structures such as bridges is to be carried out with the help of computersoftware.   Cable-Stayed BridgesOverview   The cable-stayed bridge is one of the most advancedsolutions of its kind although it has been developed over a long time span. Thefirst approach of what we call today cable-stayed bridge has been designed over400 years ago by Veranzio, a Venetian engineer. Veranzio design consisted in abridge with more diagonal chain-stays (Kavangh, 1973). Although, the popularityof the cable-stayed bridge rise in the 19th century when elements from bothsuspension bridge design and cable-stayed bridge design were combined; suchdesigns can be seen in the Albert Bridge, the Brooklyn Bridge or Bath (VictoriaBridge).

In the early 20th century the cable-stayed bridge has seen a decreasein its application as most large gaps were solved using suspension bridges andsmaller gaps were approached by construction fixed reinforced concrete bridges. In the late 20th century we see a new age of the cable-stayed bridges astechnologies advances; using combinations of steel and concrete and using largermachines allows cable-stayed bridge designs for large and medium spans. The modern approach at this type of bridge design consistsof structural steel or reinforced concrete decking, towers that are connectedto each in-between using tension members. These characteristics give cable-stayedbridges two strong advantages over other design solutions; aesthetic design andefficient use of materials. Today, the solution of the cable-stayed bridge isdue to Western European engineers' research on acquiring the highest structuralperformance from modern material combinations (Troitsky, 1972). In the past few decades the cable-stayedbridge design has been used frequently for medium span solutions.

Nevertheless, recent advancements in the construction and civil engineering fields will enablemore frequent use of cable-stayed bridges for long span approaches. In order for this modern advance structures to have suchoutstanding structural performance, the use of modelling and analysis is neededto eliminate most of the uncertainties and flows in the initial design. Therefore, traffic loading, wind loading and earthquake effects upon the structure must betaken into account and simulated with the use of FEA. Structural characteristicsOverview Cable-stayed bridges are based on a structural systemwhich consists of three main elements: deck, pylons and cables. An orthotropic deckingis placed on top of continuous girders, which consequently are supported bydiagonal strayed-cables connected from the girders to the main piers.

In theapproach of cable-stayed bridges, pylons form the main load-bearing structure. In these types of bridges, the load acting onto the deck is transferred to the girdersthan the cables in tension take the load to the pylons that subsequently dissipatethe load into the ground. In terms of static horizontal forces, cable-stayedbridges balance them in order to control pylon heights and keep them within areasonable range. Due to the way the load is transferred between the members ofthe bridge, this design has a low centre of gravity which enables a highearthquake resistance. Deck This is the roadway element of the cable-stayed bridgeand its main load comes from traffic such as train, trams or vehicles. It canbe made out of structural steel, reinforced concrete or even a compositesteel-concrete.

As this is directly connected to weight it can impact theentire construction not only in terms of load and time but also in terms ofcost. Therefore, the choice of material for this part of the bridge is crucial. The most commonly used approach in modern era for the deck is choosing acomposite steel-concrete solution. This gives the best outcome in terms ofstructural performance and weight. Pylon The pylon is the element of the bridge that dissipatesthe weight and live load, acting upon the bridge, into the ground. This is usuallymade out of reinforced-concrete and can have various shapes such as A-frame, single pylon, trapezoidal pylon or twin pylon. The shape of the pylons is chosenupon considering factors such as length, aesthetics or stayed-cables type. There are three main bridge systems in terms of pylon position and shape: singleplane system, two-vertical plane system and two-inclined plane system.

Cables These elements transfer the dead load of the acting uponthe deck to the pylons. Usually these members are post tensioned in order to amelioratelateral deflection of pylons and vertical deflection the deck. Today, fourmajor types of stayed-cables are used: parallel-wire cables, locked coilcables, stranded cables and parallel-bar cables. Depending on the arrangementof the stayed-cables in between the bridge deck and the pylons, there are fivemain systems of bridges: mono system, harp system, fan system, semi-harp systemand star system.

Abbreviations such as asymmetric cable-stayed bridges can beseen. Basarab Overpass and theCable- Stayed BridgeHistory & Overview Basarab Overpass is the largest andmost complex infrastructure project in Romania for the last 20 years. Thisproject was meant to reduce the traffic within the canter of Bucharest andcomplete the road ring of Bucharest's city centre. This project has had arather long span of completion, starting in 2004 and finishing in 2011. Thisstructure consists of 4 main parts: Grozavesti Viaduct, the 120 m arched bridgeover the River Dambovita, the Orchidea Viaduct and the most outstanding, thecable-stayed bridge over the rail tracks converging from the main train stationin Bucharest. " The Basarab Viaductmakes up the highway and tramway junction between the Titulescu Avenue– theOrquídeas Highway- the Grozavesti Bridge – Vasile Milea Avenue (for thetramways and the Grozavesti Highway, thus closing the main circulation ringroad in northwest Bucharest. The idea for this passage dates from1930, but by 1940, only the metal Basarab Bridge had been achieved, which covereda length of approximately 100 metres above the railway lines. Today, the new passage is beingexecuted as an arch over the places where the old city quarters came intobeing.

Its history begins in 1863 when MrEffingham Grant, Secretary to the British Consul in Bucharest, married thedaughterof Ana Golescu (the daughter of a Romanian noble), constructed the firstfoundry in Bucharest, near the “ Earth barrier”. During this time, Grant cultivated orchids on the patio of his house and these were the onlyorchids in Bucharest at the time, this lead to the Basarab highway beingrenamed to “ The Orchid Highway”.
Nowadays, the Basarab Bridge is notonly an arch across time and history, but will probably become one of thecity’s emblems. Romanian philately has issued a special series of stampsdepicting the Basarab Bridge.

The arch bridge over the RiverDambovita is 124 metres long and its pylons are supported on footings on top of40-metre deep columns. The arches have a 180-metre front. Between the two bridges, uniquestructures in Romania, the highway and tramway traffic operates along a 1, 500-metrelong pre-stressed concrete viaduct, including the access ramps that employed aninnovating tensioning method and which, just like the bridges, includes anadvanced seismic protection system, applied here for the first time in Romania. The Basarab Bridge connects thenorth and south of Bucharest and facilitates the traffic in the area, thuscompleting the main movement ring road in the northwest of the city. Because of its construction, theBasarab Bridge becomes the largest intermodal point in Romania, joining tramwaylines on the surface and below it, trolleybus lines, metro lines, two railwaystations, as well as bus stations for national and international transport. ” – Ciudad FCC: BasarabViaduct Location This structure is located near the Northern TrainStation.

As mentioned above the largest and most impressive part, the cablestayed bridge passes over the train tracks converging from the main trainstation in Bucharest (North-West). Specification of thecable-stayed bridge Length: 365m; Width: 44 m; Bridge type: semi-harp (asymmetric); Pylon type: twin pylon (H-frame), single planesystem; Pylon height: 80 m; Pylon foundations: pile(diameter – 1. 5 m, depth – 36 m) Number of cables: 30 (on each pylon). This cable-stayed bridge includes stair access to themetro station and also a tram line and station in between the strayed-cables, having roadways in each direction separated by the tram line. Members involved in thecable-stayed bridge project Beneficiary: Mayorof Bucharest; Designer: CarlosFernandez Casado, Spain; Contractor: BBR(Grup FCC), Coifer-Martifer. Social Impact & Outcome This project was an outstanding one. The cable-stayedbridge has been declared the widest bridge in Europe, of its kind, and the onlyone that has access to a metro station, a tram station and accommodates vehicletraffic as well. Also, it helped reduce the traffic in the city centre by 40%.

Although, this project has led to the demolition of 25 buildings and it has exitedthe budget with 140 million Euros after it had been estimated that theconstruction will not exceed 60 million Euros. Solution The project’s biggest design problem has been passingover the train tracks converging towards the train station. In the end the mostsuitable approach in passing over the train tracks has was the construction ofa cable-stayed bridge as this was the only solution that did not require themain train station in Bucharest to temporary be closed. This is due to theposition of the twin pylon which could was able to be placed outside the traintracks. MethodologyIntroduction Finite Element Model Future Work Analysis of a two dimensional model will be conducted, using Oasys GSA software. Several materials and element sizes will be verifiedfor the same structural system used in the design of cable-stayed bridge presentin the Bucharest Overpass. Three-dimensional models of all main elements (decking, cables, tower) of the above bridge willbe simulated in MIDAS Civil and Ansys Structures. With the finial goal ofconstructed a full three dimensional model of the cable-stayed bridge ofinterest.

A third stage will be carried out to compare dataobtained from both two and three dimensional models to find the most idealdesign model for the location and requirements imposed by the whole BasarabOverpass project. Gantt Chart Referencing Tao. Zhang and ZhiMinWu. Dead Load Analysis of Cable-Stayed Bridge. In International Conferenceon Intelligent Building and Management (CSIT’11), pages270 – 274, 2011. Pownuk A., (1999), “ Optimizationof mechanical structures using interval analysis”, Computer Assisted Mechanicsand Engineering Sciences, Polish Academy of Sciences.

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