Software Development for Dynamic Analysis of Structures

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Abstract—**The main objective of the project is to develop a software system for the dynamic analysis of structures like SDOF and MDOF system further as MDOF involving calculation of dynamic responses like displacement, rate and acceleration varied with reference to time. The topics coated below this square measure Duhamel's integral, calculation of natural frequencies, mode shapes of MDOF system and for continuous system (systems with distributed mass and snap particularly beams). Response spectrum is that the graphical plot of most responses quantities like displacement, rate and acceleration of SDOF system with reference to natural fundamental quantity (or) natural frequency (or) damping quantitative relation. The software system is employed to seek out out as follows: - i. Calculation of responses thanks to vibration like free and made vibration, damped and undamped vibration. ii. Dynamic performs like harmonic function (sine and cos functions) and arbitrary load functions (bomb blasting and earthquake loads). iii. Response Spectrum construction. iv. Dynamic analysis of SDOF, MDOF and continuous systems. even if such a lot of commonplace software system package like ETABS, SAP 2000, STAAD professional and shortly. This software's won't be helpful for the fundamental for learners. The salient options of the software system as follows: - i. promptly helpful for the fundamental learners of structures particularly for Post Graduate students and Industrialists. ii. it'll promptly offer the output a lot of interpretation and correct results. iii. This software system is tired step by step calculations for every are going to be done. iv. Analyzing time are going to be less compared to different software's used for the analysis of straightforward structures. v. Indian codes solely victimisation for the analysis further as manual calculation are going to be done. The results of this software system is being compared with the results different commonplace software's offered and therefore the corresponding cryptography are going to be tired C# artificial language and .NET framework.**

Keywords- structural dynamics, software, development, structures, response spectrum

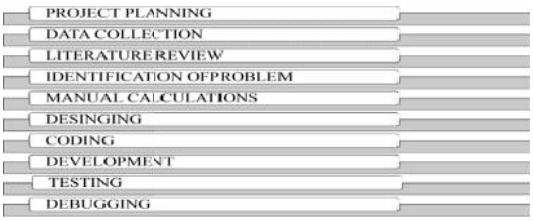
I. INTRODUCTION

Structural analysis is especially involved with searching for the behaviour of a body once subjected to force. This action is within the style of load thanks to the burden of things like folks, furniture, wind, snow, etc. or another reasonably excitation like associate degree earthquake, shaking of the bottom thanks to a blast near , etc. In essence of these masses square measure dynamic, together with the self-weight of the structure as a result of at some purpose in time these masses weren't there. the excellence is formed between the dynamic and therefore the static analysis on the idea of whether or not the applied action has enough acceleration compared to the structure's natural frequency. If a load is applied sufficiently slowly, the inertia forces (Newton's 1st law of motion) is unnoticed and therefore the analysis is simplified as static analysis.
E.D. Sotelino et al (2003) [3] during this work worries with a number of the parallel algorithms that are developed during this field. additional specifically, it's a survey of parallel algorithms that square measure of interest to structural engineering. Such algorithms embrace parallel solvers direct and unvaried for linear systems of pure mathematics equations, techniques for the parallelization of the finite part methodology, and synchronic time-stepping algorithms for the answer of the equations of evolution arising in structural dynamic issues. 28. Xiao Liang and Khalid M. Mosalam et al (2018) [28] during this work the validation of implementing the algorithmic program is incontestable employing a geometrically nonlinear setup downside with a closed-form precise resolution. Moreover, comparisons between the projected algorithmic program and

Newton-Raphson sort algorithms square measure bestowed victimisation many numerical examples from structural statics and dynamics. Finally, the measurability of the projected Lyapunov- based mostly algorithmic program is mentioned via adaptive shift of nonlinear resolution algorithms at the problematic time steps. Most current seismal style codes and practices square measure supported elastic analysis strategies, like the response spectrometry methodology and therefore the linear time history analysis methodology. Response spectrometry is one among the foremost common strategies for seismal analysis of structures. By eliminating the time variable, the response spectrum methodology finds the most structural response from a given style response spectrum of ground motion. This methodology provides designers with an easy however rational basis for deciding the most responses of structures below earthquake loading. whereas it's easy and simple to use, seismal style victimisation such associate degree analysis methodology is unvaried naturally. The inertia generated earthquake masses determined from the planning spectrum could end in structural responses that modification whenever the structure is changed. in step with Sahinyavuz (2016) [22] says the method is sustained till the steady-state worth is some reached. The analytical resolution is given by victimisation the uranologist rework methodology to envision the validity of the Newmark resolution. it's ascertained that the numerical and analytical results square measure in sensible agreement. the mixing of the management action into Newmark resolution as bestowed during this study is extended to finite part solutions to simulate the management of advanced mechanical systems. Gangsig Shin (2016) [16] says most of the unreal time histories square measure generated from the given response spectra. getting the response spectrum from a given time history is undemanding. However, the procedure for generating artificial time histories from a given response spectrum is tough and complicated to grasp. Thus, this paper presents an easy time-domain methodology for generating a time history from a given response spectrum; the strategy was shown to satisfy conditions derived from nuclear restrictive steering.

Dynamic analysis may be done mistreatment some commonplace soft wares like ETABS, SAP 2000, STAAD professional V8i, RAM Structural System, SAFE etc... square measure the some soft wares utilized in the technology. These analysis tools for dynamic analysis won't provide the essential plan concerning the structural dynamics. that the rechecking of those error are tough while not knowing the fundamentals. These softwares square measure chiefly supported the ASCE, Eurocodes and bachelor's degree codes. These limitations may be corrected mistreatment these new softwares that goes to be done as a Project. Of this computer code development, mistreatment the article destined artificial language C# originate within the Microsoft Visual Studio and a framework. web for upgrading windows. These softwares may be done mistreatment these language mixtures writing may be done. Study of response spectrum for west zone is needed as a result of the powerful earthquake that stricken the tannic acid space in Gujarat at 8:46 am on twenty six Jan 2001 has been the foremost damaging earthquake within the last 5 decades in India. The M 7.9 quake caused an oversized loss of life and property. Over 18,600 persons square measure rumored to be dead and over 167,000 cut. The calculable economic loss thanks to this quake is placed at around Rs.22, 000 crores. consistent with Indian science Department (IMD), twenty one out of twenty five districts within the state were wholly destroyed and tannic acid was the worst affected district, followed by Ahmedabad. IN Ahmedabad a ten-story building (front), a part of the Mansi flat complicated, is seen within the Vastrapur space of Ahmedabad folded. The 600 year previous monument was among the handfuls of ancient monuments that partly folded or were broken throughout the earthquake. Structures made on the soil that undergoing within the deformation throughout ground motion (Earthquake) that deformation or amendment in behaviour delineate by the response of the structure within the kind of Deformation, speed and Acceleration. Response spectrum is that the construct that deals with the most response of the infinite series of elastic single degree of freedom system (SDOF) having completely different values of natural amount Volunteer State in second. currently days the structures square measure designed consistent with thought of response recorded by the past earthquakes.

II. METHODOLOGY



III. GATHI – DYNAMIC ANALYZER

A. Topicscovered

- ✓ SDOF
- ✓ MDOF
- ✓ ContinuousSystem

A.1. SDOF

When one variable can describe the motion of a structure or a system of bodies, then we may call the system a 1-D system or a single degree of freedom (SDOF) system.

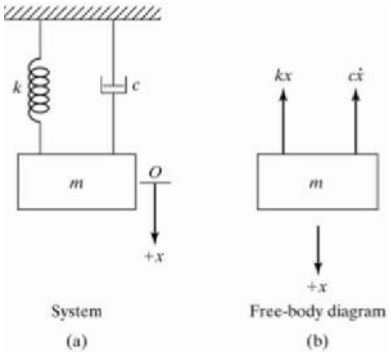


Fig 3.1 Single Degree of Freedom System

Table 3.1 of topics under SDOF

S. NO	Topics
1	Undamped Free Vibration
2	Damped Forced Vibration
3	Undamped Forced Vibration
4	Damped Forced Vibration
5	Duhamel's - Rectangular
6	Duhamel's - Triangular
7	Duhamel's – Half sine wave

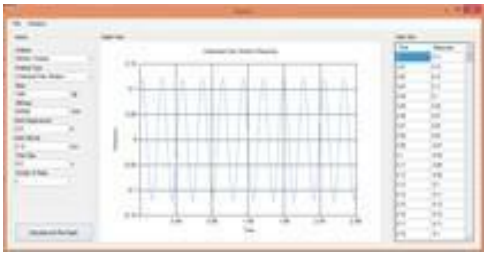


Fig.3.2 GUI of GATHI

Fig 3.3 Coding Sample of GATHI

IV.VYUHA – SESMICANALYZER

A. Strong Motion Studies inIndia

Strong ground motion is that the sturdy earthquake shaking that happens on the brink of (less than concerning fifty metric linear unit from) a actuating fault. The strength of the shaking concerned in sturdy ground motion typically overwhelms a seismometer, forcing the employment of accelerographs (or sturdy ground motion accelerometers) for recording. The science of sturdy ground motion conjointly deals with the variations of fault rupture, each in total displacement, energy discharged, and rupture speed. As seismal instruments (and accelerometers in particular) become additional common, it becomes necessary to correlate expected injury with instrument-readings. The previous changed Mercalli intensity scale (MM), a relic of the pre-instrument days, remains helpful within the sense that every intensity- level provides AN noticeable distinction in seismal injury.

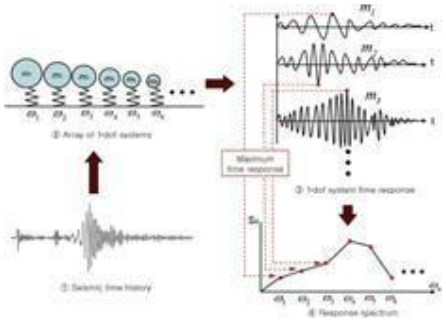


Fig 4.1 Concept of response spectrum in degree of freedom

B. Elastic Design ResponseSpectra

Most seismal style is predicated on representing the earthquake actions within the kind of equivalent static force applied to the structure. These forces square measure determined from the most acceleration response of the structure underneath the expected earthquake- evoked ground shaking, that is pictured by the acceleration response spectrum. The place to begin is AN elastic response spectrum, that is after reduced by factors that account for the capability of the structure to dissipate the seismal energy through dead deformations. the aim of

representing earthquake actions during a seismal style code like EC8 is to avoid the requirement of winding up a site-specific seismal hazard analysis for each engineering project in seismically active regions. For non-critical structures it's usually thought-about adequate to produce a zonation indicating the degree of expected ground motions throughout the region of relevancy of the code then to use the parameters pictured in these zonation's, along with a classification of the near-surface earth science, so as to construct the elastic style response spectrum at any given web site.

C. Newmark's Method

The Newmark-beta technique may be a technique of numerical integration wont to solve differential equations. it's wide utilized in numerical analysis of the dynamic response of structures and solids like in finite part analysis to model dynamic systems. the strategy is called when Nathan M. Newmark, former prof of technology at the University of Illinois, World Health Organization developed it in 1959 to be used in structural dynamics

Using the extended mean value theorem, the Newmark-β method states that the first time derivative(velocityintheequationofmotion)canbe solved as,

$$\dot{u}_{i+1} = \dot{u}_i + \Delta t \ddot{u}_\gamma$$

where

$$\ddot{u}_\gamma = (1-\gamma)\ddot{}_i + \gamma \ddot{u}_{n+1}\ 0 \le \gamma \le 1$$

Therefore

$$\dot{u}_{i+1} = \dot{u}_i + (1-\gamma)\Delta t \ddot{u}_i + \gamma \Delta t \ddot{u}_{i+1} \quad (1)$$

$$u_{i+1} = u_i + (\Delta t)u_i + [(0.5-\beta)(\Delta t)^2]u_i + [(\Delta t)^2]\ddot{u}_{i+1} \quad (2)$$

Because acceleration also varies withtime, however,theextendedmeanvaluetheoremmustalso be extended to the second time derivative to obtain the correct displacement. Thus, setting β to various values between 0 and 0.5 can give a wide range of results. Typically β = 1/4, which yields the constant average acceleration method, is used.

D. Newmark's Method: Linear System

Special Cases

(1) average acceleration method

(γ=1/2 $\frac{1}{2}$, β=1/4$\frac{1}{4}$)

(2) linear acceleration method

(γ=1/2 $\frac{1}{2}$, β=1/6)

1.Initial Condition

- $u_0 = \frac{\ddot{u}_{g0} - c\dot{u}_0 - ku_0}{m}$
- Select Δt
- $\hat{k} = k + \frac{\gamma}{\beta\Delta t}c + \frac{1}{\beta\Delta t^2}m$
- $a = \frac{\gamma}{\beta\Delta t}m - \frac{\gamma}{\beta}c$ and $b = \frac{1}{2\beta}m + \Delta(\frac{\gamma}{2\beta}$

2.Calculation of each time step i

- $\Delta\hat{u}_{g_i} = \Delta\ddot{u}_g + a\dot{u}_i + b\ddot{u}_i$
- $\Delta\hat{u}_i = \Delta\ddot{u}_{g\ i}$
- $\Delta u_i = \frac{1}{\beta\Delta t^2}\Delta u_i - \frac{1}{\beta\Delta t}\Delta\dot{u}_i - \frac{1}{2\beta}\Delta\ddot{u}_i$
- $\Delta\dot{u}_i = \frac{\gamma}{\beta\Delta t}\Delta u_i - \frac{\gamma}{\beta}\dot{u}_i + \Delta(1 - \frac{\gamma}{2\beta})\ddot{u}_i$

3.Repetition for the next one time step, replace 1 by i+1and implement above steps for next time step.

E. Response Time History Graph

Most current unstable style codes and practices square measure supported elastic analysis strategies, like the response qualitative analysis technique and therefore the linear time history analysis technique. Response qualitative analysis is one in all the foremost common strategies for unstable analysis of structures. By eliminating the time variable, the response spectrum technique found the utmost structural response from a given style response spectrum of ground motion. For the event of response spectrum the properties of SDOF system is employed within the Newmark's technique. Response of systems having period of time values from zeros to 4s with associate interval of 0.2 s is calculated victimization surpass sheet. Ground motion knowledge collected for 10 totally different ground acceleration in Republic of India from robust motion centre. Table 4.1 shows the earthquake details.

The following are the earthquakes

Sl no	Name Of Earthquake	Station	Initial Displacement (mm)	Initial Velocity (m/s)	Peak Acceleration m/s/s	Time Interval
1	Bhuj earthquake,2001	Ahmedabad	-1.006	-.118E02	-0.78236 m/s/s at 34.945 sec	0.005
2	Bhurma earthquake 1997	Dolpo	0.2600	- 165E-02	0.75829 m/s/s at 9.780 sec	0.02
3	Chamba earthquake 1995	Chamba	-0.3800	0.234E 02	1.2309 m/s/s at 3.020 sec	0.02
4	Chamoli earthquake 1995	Gopeshwar	0.9200	-.726E-02	-3.5283 m/s/s at 4.060 sec	0.02
5	Uttarakashi earthquake 1991	Bhatwari	-1.110	0.83E-02	-2.4200 m/s/s at 5.820 sec	0.02

The calculated response of particular earthquakewithnaturaltimeperiodTn=1secand damping ratio ξ=5% show the combined response time history graph for different ground motion with natural time period Tn=1 sec and damping ratio ξ=5%.

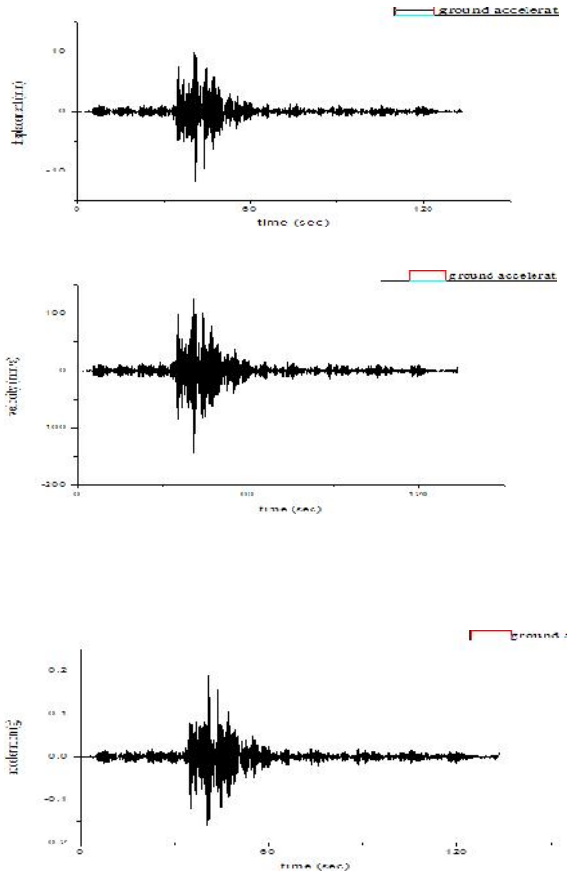


Fig 4.2:Response time history graph for different groundmotionwithnaturaltimeperiodTn=1secand damping ratio ξ=5%.

In the second step one ground accelerationandresponseofthatgroundacceleration with constant time period Tn=1 sec and varying damping ration of ξ= 5%,10%,15%, and 20% is calculated. Here the powerful Bhuj earthquake that struck the Kutch area in Gujarat at 8:46 am on 26 January2001istaken.Ithasbeenthemostdamaging earthquake

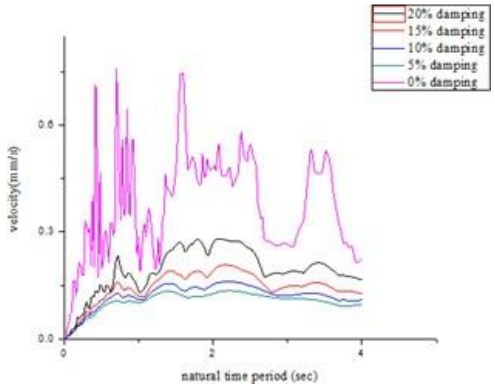
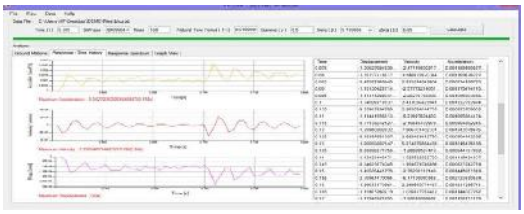


Fig 4.3: One ground acceleration and responseof that ground acceleration with constant time period Tn=1 sec and varying damping ration of ξ= 5%,10%,15%, and 20%.

F. About the Software

Developed a new software named “VYUHA”. VYUHA is software for constructing response spectrum for ground motion due to an earthquake.This software investigates thecalculation ofresponsequantitieswhicharevaryingwithrespect to natural time period, damping ratio, ground acceleration. Ground accelerations due to various earthquakes were collected from the website, Strong MotionCentre.Thissoftwareisusedforconstructing elastic design spectrum by feeding ground acceleration as input and obtain the result in the form of response quantities, such as displacement response velocity response and acceleration response. Response Spectrum is the plot of series of oscillators of varying natural frequency that are forces into motion by same base vibration.

This software is developed by .NET Framework (pronounced dot net) is a software framework developed by Microsoft that runs primarily on Microsoft Windows. It includes a large class library namedFrameworkClassLibrary(FCL)andprovides language interoperability (each language can use code written in other languages) across several programming languages. Programs written for .NET Framework execute in a software environment (in contrasttoahardwareenvironment)namedCommon Language Runtime(CLR), an application virtual machine that provides services such as security, memory management, and exception handling. (As such, computer code written using .NET Framework is called "managed code".) FCL and CLR together constitute .NETFramework.



. **Fig 4.5. Graphical User Interface of VYUHA**

Fig 4.6 Coding Sample of VYUHA

V. CONCLUSION

Guidelines have been presented for the developmentofsoftware. The inability of available software to meet the needs was discussed. Finally, a sample program specification to show how the computer could be used as is the engineer through the application of these guidelines was provided.Since the Basic equation of motion for structures subjected to earthquake is a nonlinear second order differential equation, used PRISM software to get thespectralordinatessuchasspectraldisplacement, spectral velocity, and spectral acceleration. Then response time history graph for different ground motion with natural time period Tn=1 sec and damping ratio ξ=5%, response of that ground acceleration with constant time period Tn=1 sec and varying damping ration of ξ= 2%,4%,6%,8% and 1% were calculated by using Newmark’s beta method andcompared.

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