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# AN ASSESSMENT OF THE USEFULNESS OF E-GOVERNMENT WEBSITES THROUGH USABILITY TESTING

Zahid Hussain* Aijaz Ahmed Arain** Asim Imdad Wagan***


## ABSTRACT

**Experimental usability methods are more expensive but more reliable to evaluate the usefulness of the websites. Different researchers have worked on usability testing and prove that usability testing is mandatory to eliminate various usability problems in the websites. The aim of this paper is to measure usability problems of all five Public Service Commission websites of Government of Pakistan i.e. Sindh Public Service Commission, Punjab Public Service Commission, Khyber Pakhtunkhwa/NWFP Public Service Commission, Baluchistan Public Service Commission and Federal Public Service Commission. Through these websites, federal and provincial governments recruit the public sector employees. Approximately 2500 users visit these websites daily. So this study was conducted to evaluate the usefulness of these websites. The paper presents the results for improving the websites in order to provide the better services to their intended users.**


**Keywords:** Usability Testing, Web Usability, E-Government, Objective Measures, Subjective Measures (opinions).

## 1. INTRODUCTION

The ISO 13407: 1999 has defined the usability of a product as "the extent to which the product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction, in a specified context of use".

Usability testing is performed to check required functionalities of the product and evaluate its usefulness; simultaneously quantitative data is collected by measuring time to perform given tasks [1] [2]. Another purpose of usability testing is to gather qualitative data of user's satisfaction. Qualitative data includes opinions/ comments given by the test participants as a response to the pre and post-test questionnaires [3].

The aim of this paper is to measure usability problems of all five Public Service Commission (PSC) websites of Government of Pakistan i.e. Sindh Public Service Commission (SPSC), Punjab Public Service Commission (PPSC), Khyber Pakhtunkhwa/NWFP Public Service Commission (NWFPPSC), Baluchistan Public Service Commission (BPSC) and Federal Public Service Commission (FPSC). Keeping in mind that Pakistan has huge youth population. So this study was conducted to evaluate the usefulness of these websites. This paper is organized into following sections. Section 2 briefly presents the literature review. Section 3 presents the methodology. Section 4 presents the results and finally section 5 concludes the paper.

## 2. LITERATURE REVIEW

Usability Testing is a widely useable technique for evaluating the usability of the websites by the potential users. Some argued that usability testing is only possible when website is already developed and in testing phase. In fact, usability testing can be performed on paper prototypes before development. Generally speaking more samples mean more accuracy, but this is almost impossible to invite large number of testers due to consumption of lot of time and money. According to Nielsen's research 5 users are enough to capture 85% problems on practically all of websites (http://www.useit.com/alertbox/20000319.html). Dumas and Redish argued that 5 to 12 testers are enough in a test [4]. Similarly Wilkins and Nyamapfene also pointed out that 12 to 15 test participants are sufficient to find out all the usability problems [5].

Yuan and Zhongling have chosen 11 Chinese government

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portal websites in order to increase public use and improve public satisfaction of government portal website. This paper presents an experiment method in understanding usability. It also introduces usability metrics on government portal websites [6].

Aziz et al. have done accessibility evaluation by using automatic evaluation to access the accessibility level according to Web Content Accessibility Guidelines (WCAG). Usability evaluation has also been conducted on page size, speed and broken link of Malaysian Higher Education website [7].

Nariman has explored the usability concept by investigating users of E-Government websites of the central government of Indonesia with correspondence analysis [8].

Lodhi has evaluated and assessed the existing 04 websites of Pakistani Universities from users' perspective; the technique of Usability Survey has been performed but she has applied only 3 techniques out of 10 Usability Heuristics [9].

Aliyu et al. have analyzed 05 Islamic Websites using heuristic evaluation from user perspective [10].

Zainudin et al. have evaluated the usability of two Malaysian C2C websites. Users complete number of tasks on the websites and think-aloud method has been applied during the evaluation process [11].

Liqing Huang and Mingzhu Li have selected China's C2C e-commerce business website for the research on usability evaluation system, based on an empirical study [12].

Jinling and Huan have evaluated Five B2C e-commerce Web sites in China, based on a comprehensive set of usability guidelines developed by Microsoft [13]. Al-Soud and Nakata have also evaluated E-Government websites in Jordan [14].

As no one has evaluated the usefulness of the mentioned Pakistani E-government websites, so there was a need to evaluate them to make them more useful and attractive for their users.

## 3. METHODOLOGY

The pre and post-test questionnaires have been developed and tasks have also been developed according to the events of all PSC websites to perform usability testing. The common tasks were identified which are performed frequently by the users who visit these websites. Then all five websites were tested by 50 graduates in total where each website was tested by 10 different participants from among those 50 participants. Among them 68% are fresh graduates including 10% female users but all are experienced internet users herby called test participants (see Figures 1 to 5). Before usability testing, test participants filled pre-test questionnaire regarding mainly to collect their basic demographic information. During testing, thinking aloud technique [15] was used, where one observer watched and listened them and took notes. The time duration of the test participants was also measured while performing their given tasks on the websites in seconds. After the usability testing, the test participants filled the post-test questionnaires regarding mainly to collect their opinion about the tested websites.

### 3.1 USABILITY TASKS

T1. Download Job Application Form
T2. Open Latest/ Current Advertisement
T3. Download List of Candidates
T4. Find out Written Test Result
T5. Open Recommendations/ Interview Result
T6. Find out Contact Us

The tasks T3, T4 and T5 were modified according to the website depending upon the specific nature of the job available at that time, e.g., T5 tasks was modified to find out the Final Recommendations/ Interview Results for the post of Lecturer in Islamic Studies for SPSC, Assistant Director (Technical) for PPSC, Male SST (Science Group) for NWFPPSC, Assistant Director (Labor) for BPSC and Assistant Mechanical Engineers for FPSC website.

Figure 1 shows education level of the test participants. There were only two options Graduation and Post-Graduation. The figure shows that all the test participants are graduate and no one is postgraduate.

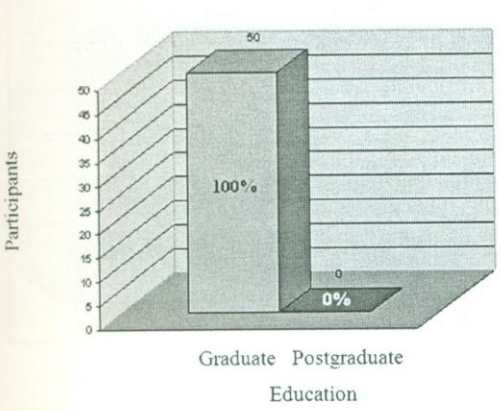


**Figure 1:** Education level of the test participants

Figure 2 shows the number of years the test participants use the internet. There were three options 1-5 years, 5-10 years and above 10 years. 38% of the test participants use internet between 1-5 years, 22% use internet between 5-10 years and 40% use internet for more than 10 years.

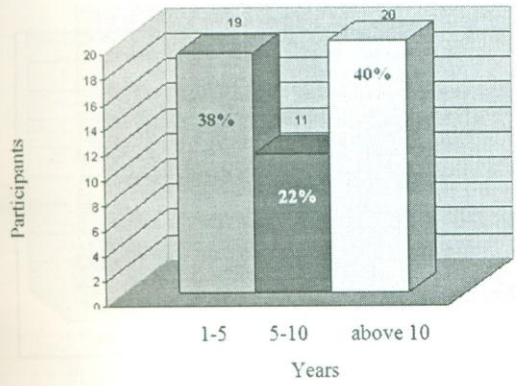


**Figure 2:** Internet usage by participants in years

Figure 3 shows age group of the test participants. There were three options 20-30 years, 30-40 years and 40-50 years. 68% of the test participants are aged between 20-30 years, 24% between 30-40 years and 8% between 40-50 years.

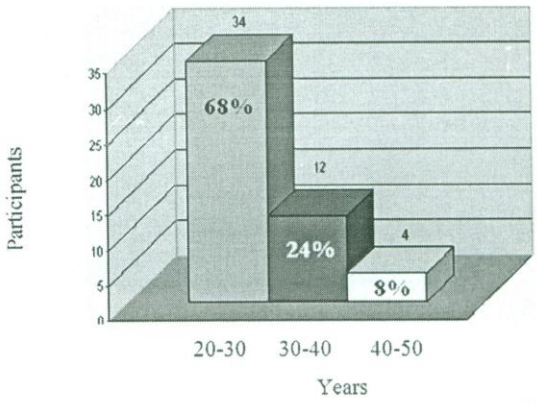


**Figure 3:** Age group of the test participants in years

Figure 4 shows gender of the test participants where 90% are male and 10% are female.

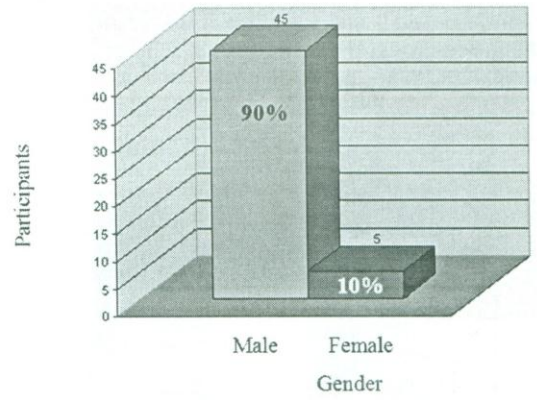


**Figure 4:** Gender of the test participants

Figure 5 shows internet usage of the test participants. There were 5 options e.g. Daily (D), Weekly (W), Monthly (M), Occasionally (O) and Never (N). All the test participants use internet where 92% use it daily and only 8% use it weekly.

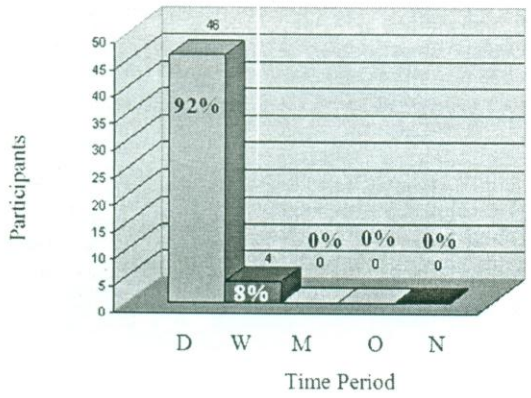


**Figure 5:** Internet usage of the test participants

## 4. RESULTS

### 4.1 OBJECTIVE MEASURES

Figure 6. shows the results of all tasks of SPSC website, tested by 10 participating users. T6 is the worst task performed by the test participants which took on average 50 seconds as they could not locate it immediately. And T2 is the best task as it took on average only 19 seconds by the test participants to carry out it.

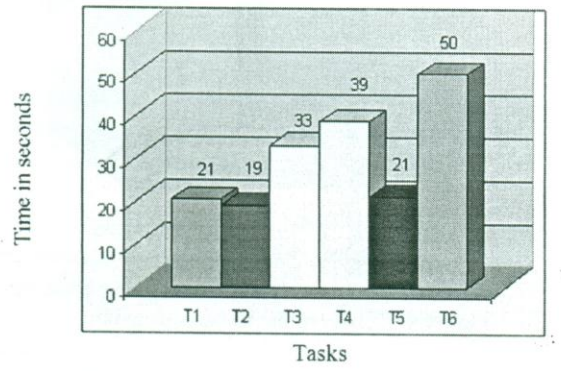


**Figure 6:** shows result of all tasks of SPSC

Figure 7 shows the results of all tasks of PPSC website, tested by 10 users. Task No. 1 is worst one as it took on average 27 seconds. As user could not locate it immediately. And Task No. 6 is best one as it took on average only 5 seconds. T3 shows zero which means that this task was not present in the website.

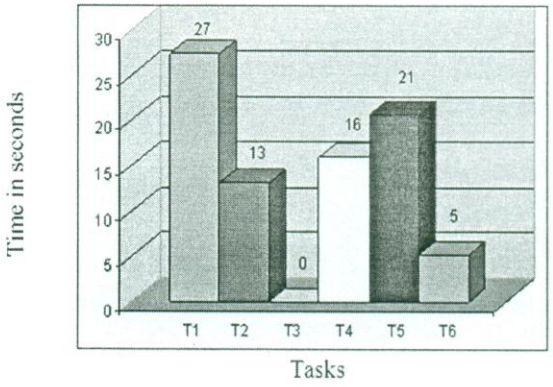


**Figure 7:** shows result of all tasks of PPSC

Figure 8 shows the results of all tasks of NWFPPSC website, tested by 10 users. Task No. 2 is worst one as it took on average 44 seconds. As user could not locate it immediately. And Task No. 6 is best one as it took on average only 8 seconds. T3 shows zero which means that this task was not present in the website.

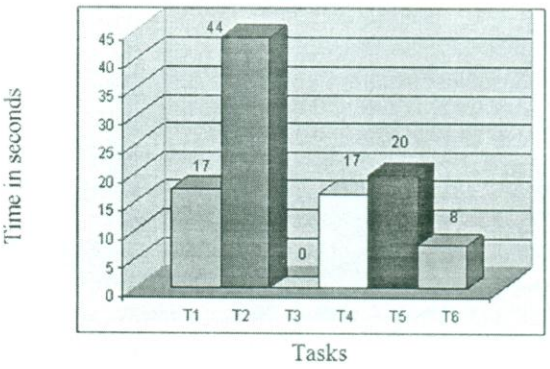


**Figure 8:** shows result of all tasks of NWFPPSC

Figure 9 shows the results of all tasks of BPSC website, tested by 10 users. Task No. 2 is the worst one as it took on average 20 seconds. And Task No. 6 is best one as it took on average only 4 seconds. T3 shows zero which means that this task was not present in the website.

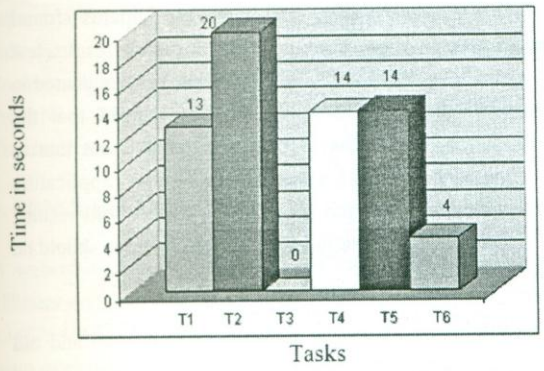


**Figure 9:** shows result of all tasks of BPSC

Figure 10 shows the results of all tasks of FPSC website, tested by 10 users. Task No. 5 is worst one as it took on average 30 seconds. And Task No. 6 is best one as it took on average only 3 seconds.

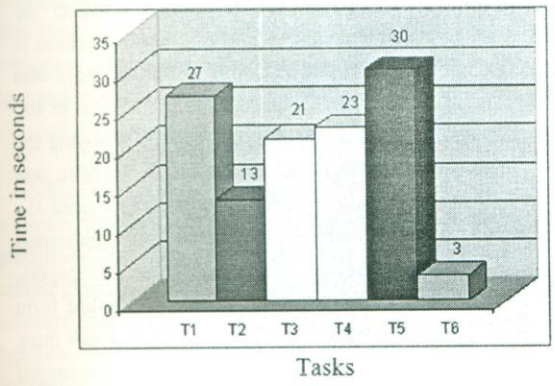


**Figure 10:** shows result of all tasks of FPSC

Figure 11 shows the average results of all tasks of all 5 PSC websites, tested by 50 users. Task No. 1 is worst one as it took on average 22 seconds. And Task No. 6 is best one as it took on average only 5 seconds.

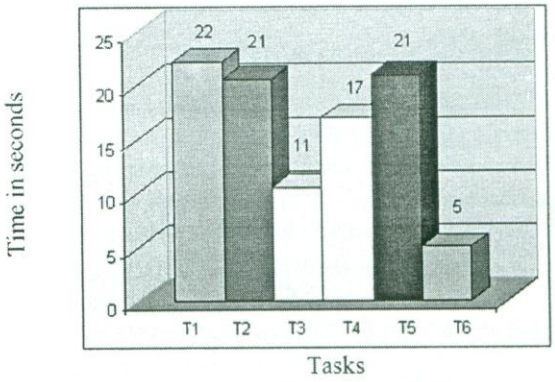


**Figure 11:** shows overall result of all 5 websites

**4.2 SUBJECTIVE MEASURES (OPINIONS)**

*(a) Post Test Questionnaire*

Following questions were asked in the post test questionnaire:

1. What features of this website were vague or confusing to you, if any?
2. What is your impression about navigating the site? Does it seem easy or difficult? What makes it that way?
3. What else should be included on this website?
4. What did you like best about the site?
5. What did you like the least?
6. Do you think some people would face problems using this website? Have you faced any problem? If any, then which problem(s)?
7. Would you like to make any other comment about this website?

The post-test questionnaires were filled by the test participants after the usability test to know their remarks, opinions, suggestions, good and bad features of the websites, as well as what type of difficulties they have faced while visiting the websites. The participants filled these questionnaires with their candid opinion after spending time on these websites and accessing all the links, features and other facilities provided on these

websites. The detailed findings for these websites are described below.

In SPSC website, the participants concluded that there is no vague feature in SPSC except the *Contact Us* link which they pointed out that it is not at a right place as per the standard pattern style. This result is also consistent with the findings of the objective measures (usability test) where this task (T6) is the worst task performed by the test participants which took on average 50 seconds. The test participants mentioned that the navigation is easy and they can approach their required links easily. Furthermore, they are of the opinion that some links and features are still missing and these must be added, such as the candidate's application status, archiving of old results, online payment, and online form filling, etc.

As the most promising features of websites nowadays is online payment and online form filling, but SPSC as well as all other websites lack these features. In addition to the navigation, participants marked that the interface of the website is the best.

In PPSC website, the participants mentioned that the links are repeated on the same webpage such as Schedule and Feedback. The worst thing is that the Schedule link in menu shows different results than the Schedule link in tab. So it is recommended that the multiple links should be avoided on the same page or if it is necessary then the links should be consistent and must point to the same resulting page. The test participants also pointed out that the main menus are not in proper order. While they mentioned that the navigation is easy. The lacking features as desired by the participants are application status, previous question papers, archiving of old results, online payment and online form filling, etc., that must be added to make it more useful and feasible. Advertisement link is rated as best, while the Result link is rated as least. The test users are of the opinion that this website looks unprofessional, as various features of the websites give a bad impression such as use of the bottom banner, as well as frequently visited links added on master page throughout website. The good feature of the website is the facility of printing interview call letter which is not available in other four websites. Some participants also objected on the URL link address which should be gov.pk instead of gop.pk as it should be consistent with other Pakistani government's website addresses.

In NWFPPSC website, the test participants found repetition of links on same page like interview results, test result and schedule as all these links are again repeated in bottom of the website while they mentioned that the navigation is easy. The participants pointed out that to make the website more attractive and useful, application status, previous question paper, archiving of old results, online payment, and online form filling features should be added.

Best rated features of the website are site map and old papers which are unique features of this website as these features are not available in other four websites. The font style and size is not liked by the participants because those are not up to the standard. The participants also have commented that this website must contain news section and job advertisements must be on home page. Another point is that recently the province name has been changed but the URL is still http://www.nwfppsc.gov.pk. This should be changed to http://www.kppsc.gov.pk.

In BPSC website, the test participants became confused when they noticed the wrong URL www.bpsc.com.pk written on the top left of the homepage, however the correct URL which they also typed to open the website is www.bpsc.gob.pk. They also complained that there was no download tab or link for important downloads. In Job tab there was a red color banner which was annoying the test participants. Design and layout of the website was rated as unprofessional, while the participants rated the navigation as easy. They demanded that the application status/ tracking system, previous question papers, archiving of old results, online payment, and online form filling features must be added in this website. Least thing of this website was that the Job tab/section is not managed professionally and written result and interview result should have separate tab/section. The participants also commented that interface design should be improved, news section and important links must be added, and website should support all famous browsers. Some of the participants have also objected on the use of gob.pk in its URL instead of gov.pk.

In FPSC website, there is a News/ Alert section instead of Written Test Result section and Recommendation section displayed Press Note instead of Job names. The feature demanded by the participants and that must be included in the website are application status, previous question

papers, archiving of old results, online payment, and online form filling. The Least liked feature was Recommendations section which should be written as Press Note. The participants also pointed out that Written Test result should have separate section.

## 5. CONCLUSIONS

A website is accepted by its users when it is effective, efficient and useful as well as if it satisfies its users (ISO 13407: 1999). All five Pakistani E-government websites were evaluated to find out their usability and usefulness for their users. Almost all the websites have flaws in their designs. In this regard, our results are consistent with [5] [11] and [14]. These flaws were pointed out and it is recommended that these websites should be redesigned to remove these flaws. The test participants also demanded new features in these websites which should also be implemented. Again our results are consistent with [14]. Only two websites have already implemented the Task 3: *Download List of Candidates,* the remaining websites should also implement this important feature. Although these websites have also good features for the use of the intended audience but they do not fully satisfied the user. This result is consistent with Jingling and Huan [13]. The consistent features that the participants demanded were: application status, previous question papers, archiving of old results, online payment, and online form filling.

Usability testing involves the users to evaluate the software product; however standard benchmarks and guidelines like heuristic evaluations are applied by usability professionals themselves to further evaluate the software products. The future work will focus on applying heuristic evaluation techniques on the mentioned websites for further improving the user experience of the users.

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# AN ANALYSIS OF THE STATE OF AGILE SOFTWARE DEVELOPMENT PRACTICES

Mohammad Ali Soomro*, Zahid Hussain**, Safeeullah Soomro***


## ABSTRACT

**The software development is both art and science. The development of a successful software product is very difficult; the process of designing software has also been frustrating as the developing process needs to welcome a constant pace of changing requirements. Recently, agile software development methods have gained popularity in industry and are claiming to be the best choice to design the successful software products and they also welcome the continuous changing requirements in this modern era of social computing and Web 3.0. This paper presents results from the online surveys conducted from 2006 to 2010. The results show the state of agile software development, particularly Extreme Programming, and its practices.**


**Keywords**: Agile Software Development, Extreme Programming, Online Survey

## 1. INTRODUCTION

The success of the software products depends upon many factors; among them the software development method plays an important role. The development of a successful software product is very difficult, the process of designing software has also been frustrating [1], so the designing process needs to welcome a constant pace of changing requirements. Recently, agile software development methods have gained popularity in industry and are claiming to be the best choice to design the successful software products and which also welcome the continuous changing requirements in this modern era of social computing and Web 3.0. Agile software development methods consist many methods, the well known agile methods are: eXtreme programming (XP), Lean software development, and Scrum [2]. All these methods follow values and principles which are written in agile manifesto (agilemanifesto.org). Each method has also various practices or techniques to be followed during software development. Mostly these methods are light weight [3] and support iteration planning, continuous integration, team collaboration and incremental based environment. Software developing communities also, sometimes, integrate Scrum and XP methods in the designing of software products. XP is the most widely used method of agile software development which consists values (simplicity, feedback, courage and communication), principles (which are based on values) and practices. Few of the practices are continuous integration, pair programming, iteration planning, simple design, test driven development, whole team, small releases, sustainable pace and onsite customer [4]. Agile software development model is more suitable than waterfall software development model. Agile methods support incremental and iterative [5] development, where iteration is normally two weeks. Programmers write unit test before writing the code and then integrate it with the main program. A software product with minimum but highly important and prioritized features is delivered to its stakeholders/users. XP advocates team collaboration and a full time customer. A customer has a good knowledge in her/his domain and has a decision making capability, (s) he is the active member of a team. Onsite customer is responsible to write user stories (descriptive tasks/ features) usually written on index cards, these user stories are then prioritized by customer [6]. Programmers estimate the stories and develop the highest priority story first. The customer is fully authorized to change the priority of any story at any time or can add/remove any story thus welcoming the change. This paper presents the state of agile software development, particularly XP, and its practices.

The paper is organized as follows. Section 2 describes the methodology. Section 3. presents the results of various agile/XP practices and the conclusion is given in section 4.

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## 2. METHODOLOGY

This paper presents the results from online surveys which were conducted by Scott Ambler from 2006 to 2010. The data has been collected from www.ambysoft.com/surveys. and is freely available for the researchers to analyze it. These surveys were distributed on various groups and mailing lists, i.e., Test-Driven Development, Scrum Development, the Extreme Programming (XP), Agile Databases, Agile Modeling, Twitter feed as well as Agile Alliance LinkedIn groups, etc.

- Survey 1 (http://www.ambysoft.com/surveys/agileMarch2007.html) was conducted in March 2007, in which 781 agile professionals had participated.
- Survey 2 (http://www.ambysoft.com/surveys/practicesPrinciples2008.html) was held in July 2008, and 337 agile professionals responded it.
- Survey 3 (http://www.ambysoft.com/surveys/practices2009.html) was conducted in July 2009 where 123 IT professionals took part in it.
- Survey 4 (http://www.ambysoft.com/surveys/tdd2008.html) was conducted in October 2008, and 121 agilists participated in it.
- Survey 5 (http://www.ambysoft.com/surveys/agileFebruary2008.html) was conducted in February 2008, and was responded by 642 agile professionals.
- Survey 6 (http://www.ambysoft.com/surveys/agileStateOfArt201011.html) was conducted in October-November 2010, 180 agile respondents filled it.
- Survey 7 (http://www.ambysoft.com/surveys/howAgileAreYou2010.html) was conducted in July-August 2010, and was responded by 293 agile professionals.

## 3. RESULTS

### 3.1 PAIR PROGRAMMING

Pair programming is the well known practice of XP [7], in this practice a team of two programmers work on the same user story and on the same single workstation. The first programmer is engaged in writing the code while the second programmer views the code for checking bugs. The main advantage of pair programming is to improve design quality, reducing errors, sharing knowledge, enhancing skills of the team members and improving the communication among team members. Figure 1 shows the status of pair programming, the data has been collected from survey 1, survey 2 and survey 3. The results show that the pair programming practice has gradually increased over the years.

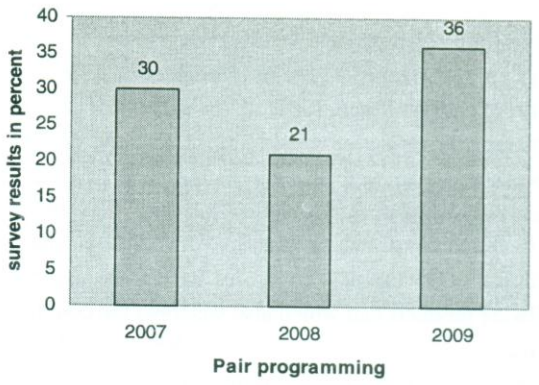


**Figure 1:** shows the status of pair programming

### 3.2 ITERATIVE PLANNING

Iterative planning or planning game is very important in agile/XP methodology for accurate estimation of tasks and their priorities [8], planning game includes both long time planning also called release planning (quarterly cycle) and short term iteration planning (weekly cycle). The team members work in same room and plan together with the customer (product owner), where user stories are estimated by developers but are prioritized by the customer [9]. Figure 2 shows the status of iterative planning; the data has been collected from survey 1, survey 2 and survey 3. The data shows the importance of this practice, especially in year 2008 it shows higher trend.

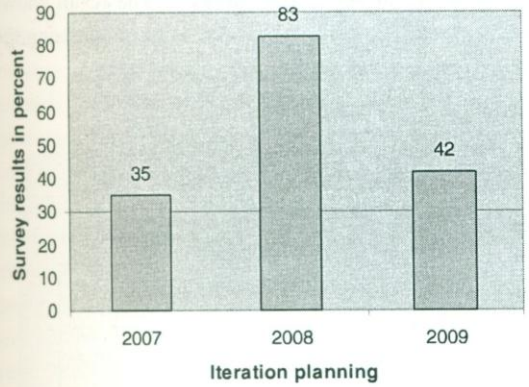


**Figure 2:** shows the status of iteration planning

### 3.3 CONTINUOUS INTEGRATION

The team of developers work on the iterations, each iteration is tested by the programmer before integrating with the main code. Each piece of code is continuously integrated with the main code daily basis even hourly/minutely basis to have a working software product all the time. The team strives to implement the required minimum features in the main code with the goal of having working software [10]. Figure 3 shows the status of continuous integration practice. The data has been collected from survey 1, survey 2 and survey 3. The results show that this practice is used on average 65%.

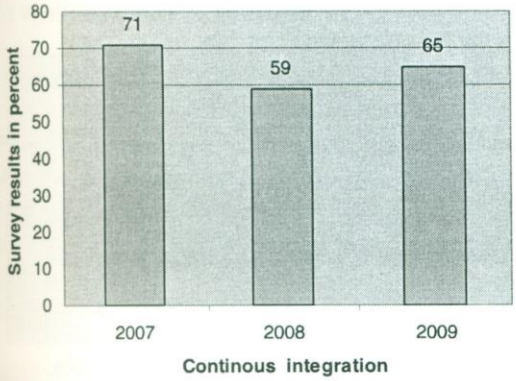


**Figure 3:** shows the status of continuous integration

### 3.4 TEST DRIVEN DEVELOPMENT

A programmer writes the unit test along with the code [10]. It is encouraged to write the tests first before the code so the tests should guide the development, hence called a test driven development. In case if the unit test fails the broken code is immediately identified and then fixed by the programmers. Figure 4 shows the status of test driven development practice, the data has been collected from survey 1, survey 2 and survey 3. On average this practice is used above 43% among the agile respondents.

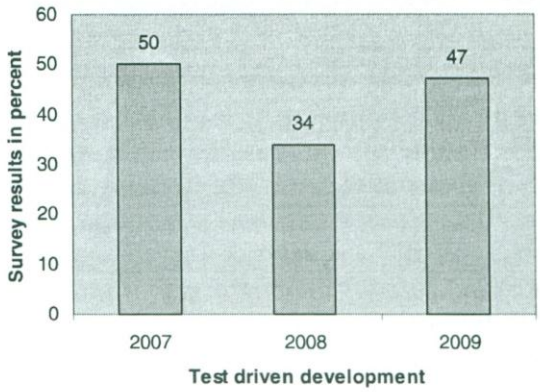


**Figure 4:** shows the status of Test Driven Development

### 3.5 COLLECTIVE CODE OWNERSHIP

Agile team members collectively own the code [10], where any part of the code can be changed by any developer in the team. In this way all the code is shared and touched by team members on rotation basis thus reducing the chances of so called truck factor. Figure 5 shows the status of collective code ownership practice, the data has been collected from survey 1, survey 2 and survey 3. The results show that this practice is being used 48% averagely among the respondents.

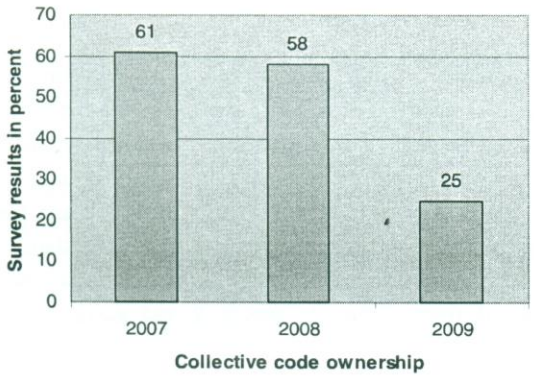


**Figure 5:** shows the status of Collective code ownership

### 3.6 CODING STANDARD

Agile methodology promotes to use the rules, standards, and consistent format and appearance from the beginning of the software development [10]. Figure 6 shows the status of coding standard, the data has been collected from survey 1, survey 2 and survey 3. The results show that this practice is used on average over 44% among agile survey participants.

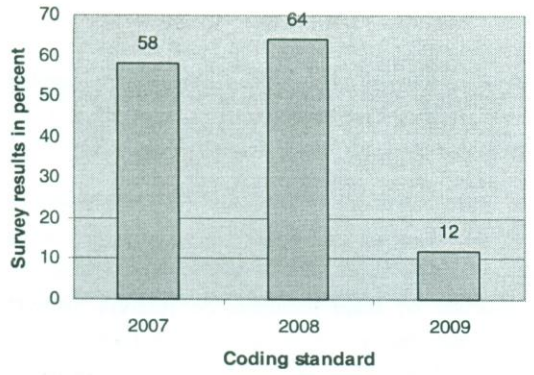


**Figure 6:** shows the status of Coding standard

### 3.7 CODE REFACTORING

Programmers continually work with latest version of iteration, huge and lengthy code is always discouraged and simple and easy code is preferred to perform the tasks, complexity is avoided and irrelevant code is removed from the main program [10]. Figure 7 shows the status of code refactoring; the data has been collected from survey 1, survey 2 and survey 3. The result shows that this practice is being used 53% averagely among the surveys' respondents.

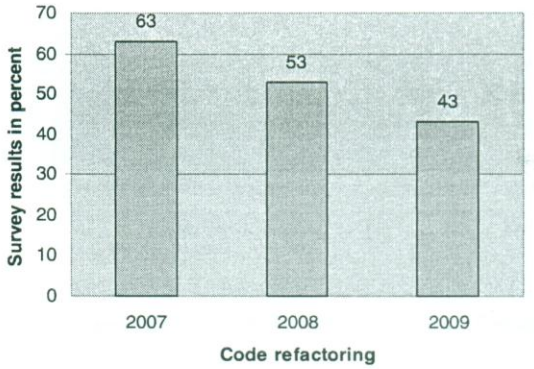


**Figure 7:** shows the status of Code refactoring

### 3.8 ACCEPTANCE TEST

This practice is valuable for the customer of the software product. This test is conducted by the customer before receiving the software. The customer is responsible to run and check the software, if any error is detected at any stage (s)he may report to the team members/developers for fixing the errors. Figure 8 shows the status of acceptance test. Data has been collected from survey 1, survey 2 and survey 3. On average, this practice is used 39% by the respondents, as indicated by Figure 8.

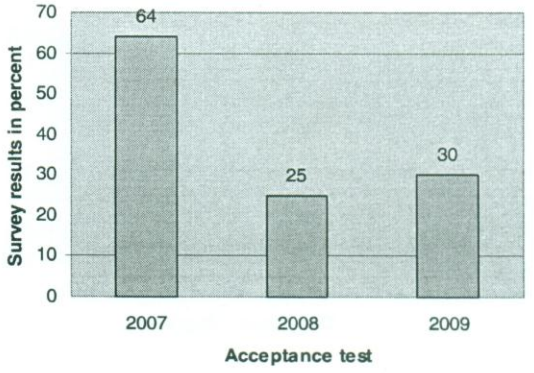


**Figure 8:** shows the status of acceptance test

### 3.9 SMALL RELEASES & ITERATIONS

Agile methods are incremental based [10], a working software is delivered to the customer in small frequent releases whereas each release is divided in small iterations. The iterations are ranged in one week, two weeks to four weeks. Through these small releases, the customer gains the confidence in the progress of the deliverable software where most essential and high prioritized features are released incrementally. Figure 9 shows the status of the iterations whereas the data has been collected from survey 1, survey 5, and survey 6. One week iteration is used over 22% averagely, two weeks iteration is used 24% averagely, and four week iteration is used over 24% averagely by the respondents.

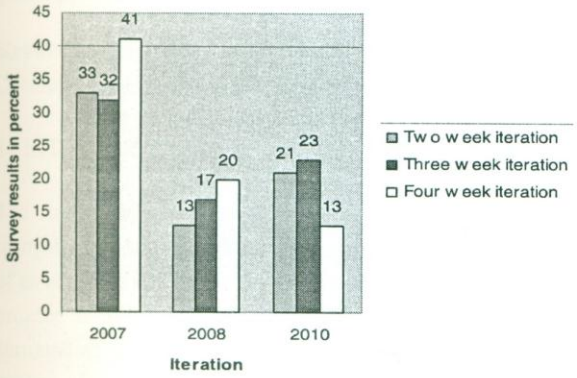


**Figure 9:** shows the status of iterations

### 3.10 WHOLE TEAM/ TEAM SIZE

In agile software development a team normally consists of 1- 10 people having diverse expertise, also called cross-cultured team [10], a customer is always be with the team for the questions and answers, and is considered as a part of the whole team. Figure 10 shows the status of whole team / team size. The data has been collected from survey 1, survey 3, survey 4 and survey 5. Mostly the team consists of 6-10 people (over 30% average).

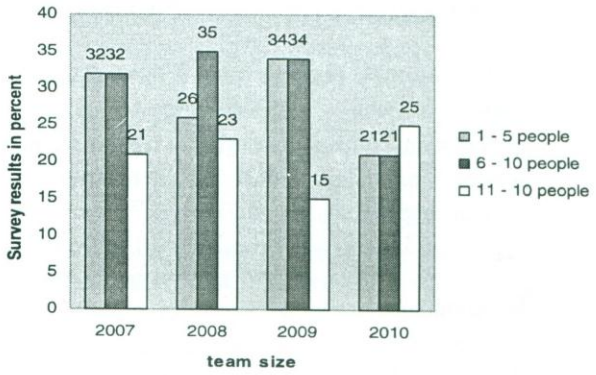


**Figure 10:** shows the status of team size

## 4. CONCLUSIONS

The agile software development has been gaining popularity in industry. This paper presented few of the practices of agile methods. The results showed that the pair programming practice has gradually increased over the years. Iterative planning as well as continuous integration have been the important practices. Test driven development, collective code ownership, and coding standard have been used over 43%. While code refactoring has been used 53% averagely among the surveys' respondents. The use of acceptance test has been declining. Two weeks iterations and four weeks iterations are quite popular in agile world. An agile team normally consists of 6-10 people, thus proving the earlier results and theories [10].

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# MATLAB/SIMULINK BASED WAVELET TRANSFORM TECHNIQUE IN WAVEFORM DISTORTION OF ELECTRICAL POWER QUALITY PROBLEMS

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## ABSTRACT

**The distorted information of waveform distortion (WFD) signals which is a type of electrical power quality (EPQ) problems is conventionally achieved with the assessment of root mean square (RMS) values, utilizing fast Fourier transformation (FFT) technique. This paper proposes Matlab/Simulink based wavelet transform (WT) technique instead of traditionally used fast Fourier transform method for root mean square assessment, in waveform distortion signals. The proposed technique of wavelet transform is simpler and more suitable for waveform distortion signals. This has been achieved, when actual RMS values of signals are compared with the RMS values obtained from Fourier and wavelet transformation calculations. Fourier transformation shows more errors in the calculation of interharmonics distortion when compared with WT technique. But in the case of stationary power system harmonics, Fourier transformation is more suitable and accurate for calculating the harmonic distortions and WT shows only good applicability and accuracy.**

**Keywords:** Electrical Power Quality, Waveform Distortion, Harmonics, Interharmonics, Wavelet Transform, Wavelet Packet Decomposition, Fast Fourier Transformation, RMS Values

## 1. INTRODUCTION

The term electrical power quality (EPQ) is also recognized as supply reliability to point out the existence of an adequate and secure power supply. More relevant in broader sense it has been known as service quality, surrounding the three aspects of reliability of supply, quality of power offered and provision of information. EPQ is defined as" any power problem manifested in voltage, current, or frequency deviations that result in failure or misoperation of customer equipment and system itself. IEEE and IEC have defined power quality disturbances into seven categories [1-2].

Transients, Short Duration Voltage Variations, Long Duration Voltage Variations, Voltage Imbalance, Power Frequency Variations, Voltage Fluctuations and Waveform Distortion which is defined as a steady state deviation from an ideal sine wave of line frequency principally characterized by the spectral content of the deviation.

In broader sense waveform distortion EPQ are subdivided into five types: known as: harmonics, interharmonics, dc offset, noise and notching. Amongst these due to huge utilization of power converters, harmonics and interharmonic of waveform distortion of EPQ are significant types to be focused in literature.

### 1.1 HARMONICS

Manufacturing or domestic non-linear loads especially the utilization of static power electronic converters and electrical drives can origin harmonic distortions. The effect of harmonics in the power system comprises the loss of data, overheating, damage to sensitive equipment, improper indication of protective relays, overloading of capacitor banks and interference to nearby telecommunication system due to high frequency harmonics.

### 1.2. INTERHARMONICS

The problem of the currents or voltages consisting of frequency components having non integer multiples of the supply frequency at which the supply system is designed to operate called interharmonics. The causes include

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variable frequency induction motors, static frequency converters and arcing devices [3-5].

## 2. ESTIMATION OF SIGNAL PROCESSING COMPONENTS

It is well in the field digital signal processing that the difference of actual wave and ideal wave is mostly compared by the technique known as rms error. This technique provides all the unwanted non sinusoidal data of harmonics and interharmonics.

Although rms (Root Mean Square) is not an inherent signal processing technique, yet it is the most used tool in case of harmonics and interharmonics calculations. Rms gives a good assessment of the fundamental frequency amplitude of a waveform. A big advantage of this algorithm is its simplicity, speed of calculation and less requirement of memory, because rms can be stored sporadically instead of per sample [6].

A great quantity of work has been focused in the assessment of amplitude and phase of the fundamental frequency as well as its related harmonics. The most important tool for estimation of fundamental amplitude of a signal is the discrete Fourier transform (DFT) or its computationally efficient implementation called fast Fourier transform (FFT). FFT transforms the signal from time domain to the frequency domain. Its fast computation is considered as an advantage. With this technique, it is potential to have an estimation of the fundamental amplitude and its harmonics with a reasonable approximation. However, window dependency resolution is a disadvantage, e.g. longer the sampling windows better the frequency resolution. FFT performs well for estimation of periodic signals in stationary state similar to harmonics; though it doesn't perform well for the detection of interharmonics or abruptly or fast changes in waveforms like transients or voltages dips [7].

## 3. INTRODUCTION TO WAVELET TRANSFORM (WT)

At present, the wavelet transform has been demonstrated to be a powerful signal processing tool in the field of communications, data compression, power system transient, de-noising signals, reconstruction of high resolution images, and harmonics estimation [8]. Wavelet provides the distribution of the power and energy with respect to the individual frequency bands. Infinite impulse response (IIR) filters have been utilized because the magnitude characteristics are much better than typical finite impulse response (FIR) filters of corresponding complexity. The competence of WT comes from the reduction in the number of coefficients as the scaling factor increases [9]. The wavelet expansion separates signal components that overlap in both time and frequency. Wavelets can be designed to fit different applications [10].

Wavelet theory is considered as the mathematical tool for expressing the models for stationary and non-stationary signals with the sets of small components known as wavelets.

$$W.T(a,b) = 1/\sqrt{a} \int_{-\alpha}^{\alpha} x(t) g\left(\frac{t-b}{a}\right) dt$$

Where a = scale, b = translation parameter and g(t) = is known as mother wavelet or the base function.

In multiresolution analysis (MRA), wavelet functions and scaling of functions are utilized as building blocks to decompose and reconstruct the signal at different resolution levels. The wavelet functions will construct the detail version of the decomposed signal and the scaling function will construct the approximated description of the decomposed signal.

Wavelet analysis deals with expansion of functions in phrase of a set of basic functions similar to Fourier analysis. However, wavelet analysis expands functions not in terms of trigonometric polynomials but in terms of wavelets, which are generated in the shape of translations and dilations of a fixed function called mother wavelet. Comparing with FFT, wavelet can acquire both time and frequency information of signal, while only frequency information can be acquired by Fourier transforms [8-11].

The continuous wavelet transform (CWT) is used to approximate harmonic and inter-harmonic of non-stationary signals. The discrete wavelet transform (DWT) has less computational complications and higher calculating speed in comparison to CWT. Preserving the distinctiveness of analysis, and increasing utilization of digital signal processing tools make DWT more practical in real applications. Thus, the application of DWT is often more common in the field of electrical power quality

because it has been quite successful in identifying various categories of power quality disturbances [11-16].

In this paper Wavelet packet transform (WPT) with decomposition method called WPD is applied which shows better results in the case of harmonic and inter-harmonic assessment due to its exclusive proper frequency bands.

## 4. WAVELET PACKET DECOMPOSITION (WPD)

The wavelet packet decomposition (WPD) of a signal is viewed as a step by step transformation of the signal from the time to the frequency domain. The upper level of the wavelet packet decomposition is the time representation of that signal. Each level of the decomposition is calculated there is an increase in the trade-off between time and frequency resolution. The bottom level of a fully decomposed signal is a. frequency representation. The convolution and decimation steps in the WPD can be interpreted as a. discrete time filtering and down sampling. Low pass filtering is followed by decimation and high pass filtering is followed by decimation [16-18].

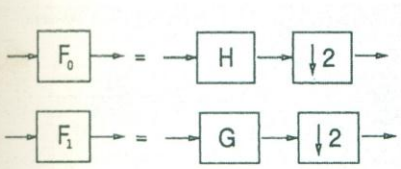



**Figure 1:** Shows convolution and decimation steps in the wavelet packet decomposition which can be interpreted as a discrete time filtering and down sampling.

As WPD is a generalization of wavelet decomposition, which offers a richer signal analysis. The atoms of WP are considered as waveforms indexed by the interpreted o3 parameters and they are scale, frequency and position.

If we are given an orthogonal wavelet function, a library of bases can be generated and is known as wavelet packet bases. These bases offer a particular way of coding signals, preserving global energy and reconstructing exact features.

WP can be utilized for several expansions of a given signal. After that, the most suitable decomposition of a given signal with respect to an entropy-based criterion is selected.

In case of WPD and optimal decomposition the simple and efficient algorithms are available. This can then produce adaptive filtering algorithms with the applications in data compression methods and coding of optimal signals.

Orthogonal wavelet decomposition method splits the approximation coefficients into two parts which gives the coarse scale vector coefficients of approximation and detail. The missing information among two consecutive approximations is stored in the detail coefficients. The consecutive details never repeat because in this process splitting of new approximation occurs.

From the figure it is evident that each vector of detail coefficient splits into two parts utilizing the same procedure as in case of approximation coefficient vector. This procedure creates very good rich analysis. Figure shows the complete 03 level binary tree of WPD. This idea of signal decomposition will be initiated from a scale-oriented decomposition. The remaining signal will be analyzed and obtained on frequency sub bands [16-18].

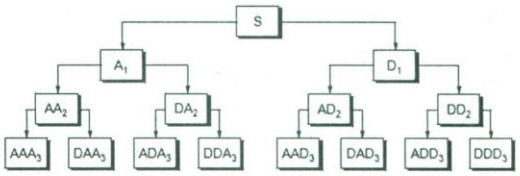



**Figure 2:** Three level tree WPD

## 4. METHODOLOGY

First choose the wavelet and its mother wavelet which is the base for accuracy. For this purpose, wavelet packet transform is tested with Daubechies as mother wavelet. But the result becomes satisfactory with dmey as mother wavelet.

Both WPT and dmey are used for WFD and coefficients are collected. This gives opportunity to calculate root mean square values which produces the difference between actual and calculated values.

This technique of calculating RMS values with WT is more suitable because it will store the data with amplitude and time both at the same time.

## 5. SIMULATION AND RESULTS

Figure 03 shows waveform distortion of first, third, fifth and seventh harmonic components having amplitude voltages 240, 84, 36 and 24 volts respectively and their FFT representation with 0.02 seconds window size.

Now proposed technique is applied with wavelet packet transform and dmey as mother wavelet. Table 01 shows the comparison of RMS values with proposed technique of wavelet and conventional fast Fourier transform.

**Table 1:** Figure 04 shows waveform distortion and their FFT representation having first and fifth harmonics with 240 and 120 amplitude volts and non integer multiple of fundamental frequency component with 120 volts whose interharmonics are at 7.770 of fundamental frequency.

| Amplitude voltage | Frequency component | rms value (actual) | rms value (WT) | rms value (FFT) |
|---|---|---|---|---|
| 240 | 50 | 169.7056 | 169.7047 | 169.7056 |
| 84 | 150 | 59.3970 | 59.2180 | 59.3970 |
| 36 | 250 | 25.4558 | 25.3017 | 25.4558 |
| 24 | 350 | 16.9706 | 16.9998 | 16.9706 |

**Table 2:** shows the comparison values with proposed technique and conventional FFT.

| Amplitude voltage | Frequency component | rms value (actual) | rms value (WT) | rms value (FFT) |
|---|---|---|---|---|
| 240 | 50 | 169.7056 | 169.7722 | 169.8969 |
| 120 | 150 | 84.8528 | 84.8528 | 81.0281 |
| 120 | 250 | 84.8528 | 84.8528 | 82.5822 |
| 00 | 350 | 00.000 | 1.8921 | 02.7837 |

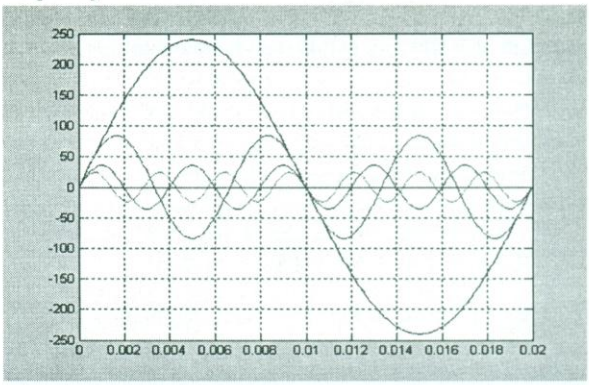
The comparisons of these two tables indicate that:

First there is big difference between actual rms values and FFT rms values in case of interharmonics. On the other hand rms values of wavelet are very close and accurate to actual rms values.

Secondly rms values of FFT are very close and accurate to actual rms values in case of harmonics.

This paper suggests a very simple technique of wavelet transform to measure and calculate the rms values and compares with actual and conventional FFT rms values. This technique uses two simple examples of harmonics and interharmonics of waveform distortion problem of electrical power quality.

It is obvious from the results that the proposed technique shows some small errors in calculating rms values of harmonics but more appropriate in case of interharmonics where FFT methods shows high errors when compared with actual values. For designing the filters of circuits having waveform distortion problems wavelet base calculated values are very useful because they not only provide accurate rms values but they also contain time frequency information.

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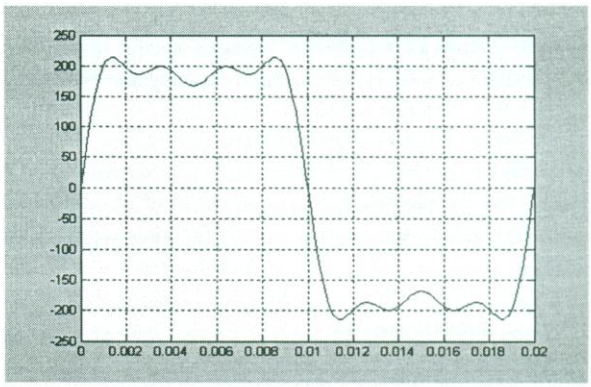


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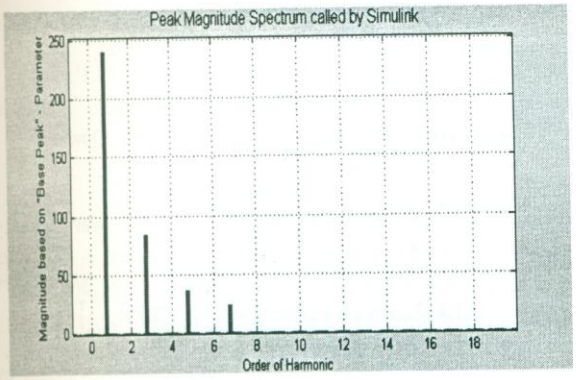
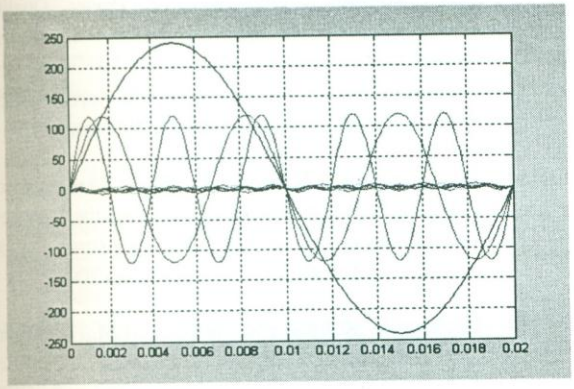



(c)

**Figure 3 :** (a) Shows waveform distortion of first, third, fifth and seventh time domain harmonic components individually (b) all components of harmonics combined and (c) shows their frequency domain (FFT) representation



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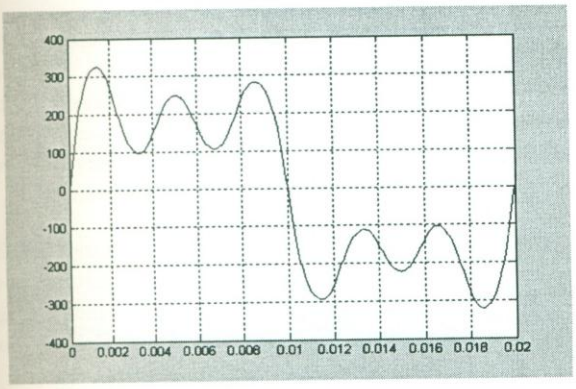

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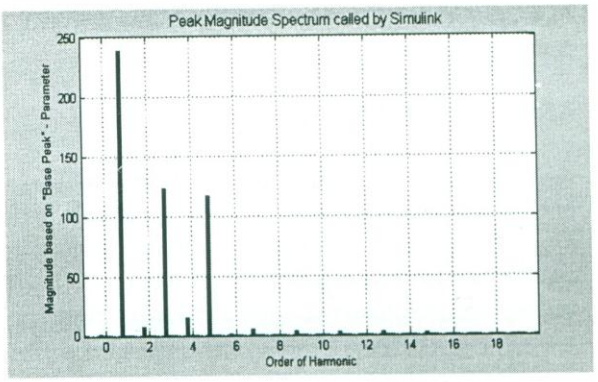


(c)

**Figure 4 :** (a) Shows waveform distortion of first and fifth time domain harmonic with non integral multiple of fundamental frequency (b) all components of harmonics combined and (c) shows their frequency domain (FFT) representation.

## 6. CONCLUSIONS

In this work, time-frequency technique of WT gives accurate distortion data in terms of frequency amplitude and time of WFD stationary signals (like harmonics and interharmonics) and this has been proved from the calculations of their RMS values.

Matlab/Simulink based technique with wavelet packet transform and dmey as its mother wavelet, suggests from its results, that the WT is easier and suitable for WFD signals when we compare the true and calculated RMS values first with conventional FFT and then with proposed WT technique.

Although proposed wavelet transform shows the applicability and behaves satisfactorily in case of stationary harmonics, where as the results of fourier transformation are more suitable and accurate.

In the case of interharmonics, wavelet transform is easier, more suitable and accurate because it shows more close values to the actual RMS values than the values calculated by FFT.

As a future work, this proposed technique of wavelet transform can be extended for the detection of voltage sag and swell. In this research, MATLAB Version 7.13 and

Simulink Version 7.8 in 2.4 GHz processor and Ram of 2GB have been utilized.

## ACKNOWLEDGEMENT

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# APPLYING HEURISTIC EVALUATION ON PUBLIC SERVICE COMMISSION WEBSITES

Aijaz Ahmed Arain* Zahid Hussain** Asim Imdad Wagan***


## ABSTRACT

**Usability is a necessary condition for survival on the web by assessing the usefulness of existing websites or developing from the scratch and then conducting its Usability Evaluation e.g., Usability Testing or Heuristic Evaluation among other HCI techniques. Heuristic Evaluation is an efficient and effective method for finding the flaws from websites on best possible cost. The aim of this research is to measure usability problems in the user interface design of 05 Public Service Commission websites of Government of Pakistan, as approximately 2500 users visit these websites daily. Accordingly, 10 usability heuristics of the famous usability expert Jakob Nielsen have been chosen to evaluate these websites. These heuristics were then further subcategorized. The results are promising and stress the need for improving the user interface of these websites so that their end-users can better utilize them.**


**Keywords:** HCI, E-Government, Heuristic Evaluation.

## 1. INTRODUCTION

Heuristic evaluation is being applied as a HCI inspection method especially in websites, to discover the usability problems in their interfaces. In this method, expert usability professionals investigate the design and interface to satisfy its conformity with existing recognized usability guidelines or Heuristics.

Heuristic evaluations most commonly carried out by a tiny set consisting of one to three evaluators. These evaluators individually analyze user interface as well as observe its fulfillment according to predefined well known usability principles. Consequently, the result of analysis will produce a list of potential usability issues or problems.

The usability heuristics or usability principles are taken from predefined lists. Preferably, usability expert applies one or more usability heuristics for evaluating and fixing the problem. To find out the more true problems pertaining to usability heuristics, more evaluators are to be involved.

This paper evaluates the usefulness of five Public Service Commission (PSC) websites of Government of Pakistan i.e. Sindh Public Service Commission (SPSC), Punjab Public Service Commission (PPSC), Khyber Pakhtunkhwa/ NWFP Public Service Commission (NWFPPSC), Balochistan Public Service Commission (BPSC) and Federal Public Service Commission (FPSC) through heuristic evaluation. In next section literature review is presented. Methodology is presented in its successor section. Results are shown in Section 4 while last section shows the conclusion.

## 2. LITERATURE REVIEW

Heuristic Evaluation is a very common and cheaper usability method used for evaluating the usability of user interface design by one or more usability experts. According to Nielsen's research one to three evaluators are enough to detect major usability problems of any website.

Almarashdeh et al. have stated that it is very important to ensure the effectiveness and efficiency of the system by measuring its usability [1]. In Pakistan there is little work done on Pakistani e-government Public Service Commission (PSC) websites using Usability Testing method. Al-Khalifa has evaluated 14 government websites of Saudi Arabia using heuristic evaluation method [2]. Aziz et al. have evaluated accessibility level by conducting automatic evaluation as well as appraisal

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on Speed, page size, and broken link of Higher Education website of Malaysia [3]. Four Pakistani Universities websites e.g. Quaid-e-Azam University, Punjab University, Virtual University and Alama Iqbal Open University have been evaluated and assessed by the Lodhi by applying just 03 Nielsen's usability heuristics out of 10 Usability Heuristics [4].

Aliyu et al. have investigated 50 religious websites by applying usability heuristics to declare quality ranking using 09 website features. They select 50 top Islamic websites through Google search. Some websites got excellent rating in terms of information authenticity [5]. Huang and Li have selected and applied seven leading indicators for improving the e-commerce website usability. Their research was based on empirical study [6]. Five (business to consumer) e-commerce websites of China have been evaluated by Jinling and Huan based on a widespread set of usability guidelines developed by market leader Microsoft [7]. Al-Soud and Nakata have also evaluated e-government websites in Jordan [8].

As only one research has been carried out on Pakistani (PSC) e-government websites using HCI/Usability techniques so there was a need to evaluate these PSC websites with more HCI/usability techniques (Heuristic Evaluation) hence making them more beneficial for the end-users of these websites.

## 3. METHODOLOGY

10 Usability Heuristics have been taken from Jakob Nielsen's heuristics [9] and have been further sub-categorized from standard heuristics [9-13].

All 05 PSC websites were analyzed comprehensively by the authors, and then separate evaluation sessions were conducted in different times. Authors applied all 50 sub-heuristics to all the PSC websites and got statistical data then compared results and declared final findings.

We had assigned the grading points as (Good=20, Fair=10 and Poor=0), e.g., if any heuristic was fully implemented by the website then the website got 20 points. If any heuristic was partially implemented by the website then website got 10 points and if any heuristic was not implemented by the website then the website got zero (0) points.

For example heuristic 3.1.1 was applied on SPSC website and got results as:

| | | |
|---|---|---|
| 3.1.1.1 = Good | got | 20% |
| 3.1.1.2 = Good | got | 20% |
| 3.1.1.3 = Fair | got | 10% |
| 3.1.1.4 = Fair | got | 10% |
| 3.1.1.5 = Fair | got | 10% |

Total points achieved by SPSC website in heuristic 1 is 70% as shown in Figure 1.

### 3.1 HEURISTICS AND SUB-CATEGORIES

*(a) Visibility of System Status*

- "Does every display begin with a title or header that describes screen contents?" [10]
- "Is it clear where you can go from the current location?" [12] [13]
- "Is it always clear what is happening from each action you perform?" [12] [13]
- "Does the user have to scroll beyond one full screen? "[11]
- "Is the page length appropriate to the content?" [11]

*(b) Match between the System and the Real World*

- "Is the vocabulary appropriate for the intended audience?" [13]
- "Are menu choices ordered in the most logical way?" [13]
- "Site structure is simple, with no unnecessary levels." [14]
- "All major parts of the site are accessible from the Home page." [14]
- "There is a clearly-identified link to the Home page." [14]

*(c) User control and freedom*

- "There is a clear exit point on every page." [14]
- "Can users easily reverse their actions?" [10]
- "Is the most important information placed at the beginning of the prompt?" [10]
- "Can users set their own system, session, file, and screen defaults?" [10]
- "No unnecessary technologies are used." [12]

*(d) Consistency and Standards*

- "Do all buttons/labels/textboxes/text/ icons/other offer consistent and meaningful information?" [11]
- "Does the system follow conventions and expectations?" [13]
- "Links are used and appear in standard web style." [12]
- "The site supports all major browsers (e.g. Internet Explorer, Firefox, Google Chrome, Opera)" [12]
- "Have industry or company formatting standards been followed consistently in all screens within a system?" [10]

*(e) Errors prevention*

- "Are solutions offered to help users recover from errors?" [11]
- "Does the user have control over the system when emergency exit?" [11]
- "Are errors avoided or minimized when possible?" [11]
- "Error messages describe what action is necessary" [14]
- "Error messages provide contact details for assistance." [14]

*(f) Recognition rather than recall*

- "Have items been grouped into logical zones, and have headings been used to distinguish between zones?" [13]
- "High levels of concentration are not necessary and remembering info: is not required." [10]
- "Are available options always clearly presented?" [13]
- "Are labels and links described clearly?" [13]
- "Do text areas have "breathing space" around them?" [10]

*(g) Flexibility and efficiency of use*

- "Are standard templates provided with easy access to personalize or modify things?" [11]
- "Can activities be done logically and easily?" [11]
- "If the system uses a pointing device, do users have option of using keyboard shortcut?" [10] [13]
- "All functionality is clearly labeled." [14]
- "No unnecessary plug-ins are used." [14]

*(h) Presentation - Aesthetic and minimalist design*

- "Is the site structure simple and clean?" [13]
- "Are the screens pleasing to look at?" [11]
- "Is there proper use of color or graphics that enhance navigation?" [11]
- "Are buttons and selections of sufficient viewable size?" [11]
- "Is text of sufficient viewable size?" [11]

*(i) Errors - help diagnose, recognize and recover from them*

- "Is sound used to signal an error?" [10]
- "Is it easy to contact support through e-mail or a web form?" [13]
- "Are prompts (Errors) brief and unambiguous?" [10]
- "If necessary, error messages are clear and in plain language." [12]
- "Do error messages indicate what action the user needs to take to correct the error?" [10]

*(j) Help and documentation*

- "Is the available help useful?" [13]
- "Navigational Help (Where am I?)" [10]
- "A site map or other navigational assistance is always readily available." [12]
- "If needed, a FAQ is available." [12]
- "If necessary, a search function is readily available" [12]

## 4. RESULTS

This section presents the results in detail. Figure 1 shows the results of all PSC websites. Five sub-categories of Heuristic 1 "Visibility of System Status" have been applied on all 05 PSC websites. The figure clearly shows that FPSC website is the best one where 90% Heuristic is implemented and NWFPPSC got 60% results hence ranked as the worst website.

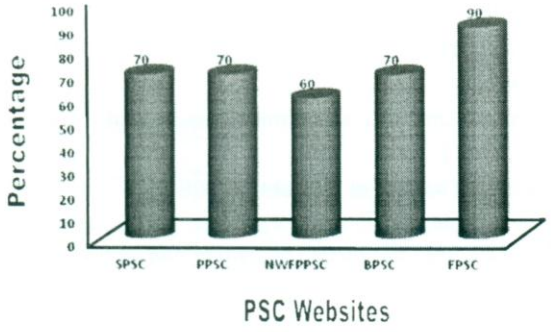


**Figure 1:** Results of Heuristic 1 "Visibility of System Status"

Figure 2 shows the results of all PSC websites. Five sub-categories of Heuristic 2 "Match between system and the real world" have been applied on all 05 PSC websites. The result shows that 80% Heuristic is implemented by FPSC website hence rated as the best one while PPSC has only implemented 50% heuristic so it is rated as the worst website.

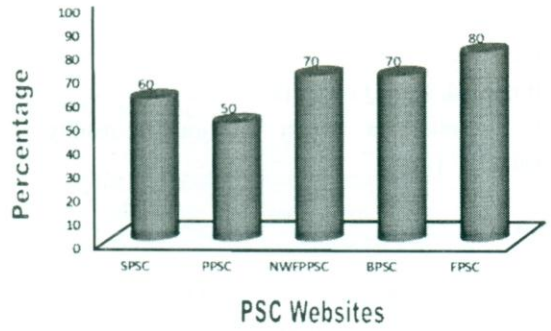


**Figure 2:** Results of Heuristic 2 " Match between system and the real world"

Figure 3 shows the results of all PSC websites. Five sub-categories of Heuristic 3 "User control and freedom" have been applied on all 05 PSC websites. FPSC website has got top position among 05 PSC websites by applying 40% heuristic and NWFPPSC website has secured only 20% so ranked as the worst website.

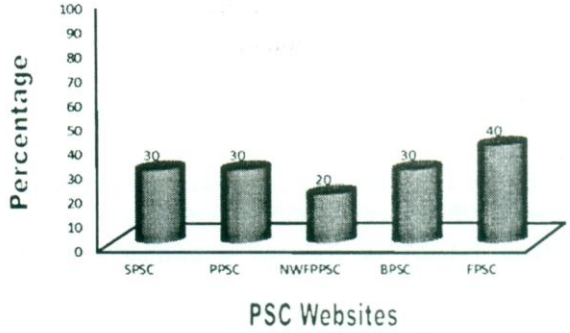


**Figure 3:** Results of Heuristic 3"User control and freedom"

Figure 4 shows the results of all PSC websites. Five sub-categories of Heuristic 4 "Consistency and standards" have been applied on all 05 PSC websites. The figure shows that FPSC website is the best one where 70% Heuristic is implemented and remaining 04 PSC websites got 50%.


**Figure 4:** Results of Heuristic 4"Consistency and standards"

Figure 5 shows the results of all PSC websites. Five sub-categories of Heuristic 5 "Error prevention" have been applied on all 05 PSC websites. Three out of five websites have online application form facility but there was no error prevention technique implemented so all five PSC websites got 0%.

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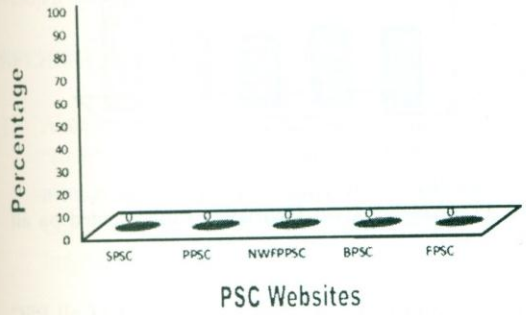


**Figure 5:** Results of Heuristic 5"Error prevention"

Figure 6 shows the results of all PSC websites. Five sub-categories of Heuristic 6 "Recognition rather than recall " have been applied on all 05 PSC websites. Heuristic 6 is 70% implemented by FPSC website so ranked as the best one and same heuristic is 40% implemented by PPSC & NWFPPSC hence ranked as the worst websites.

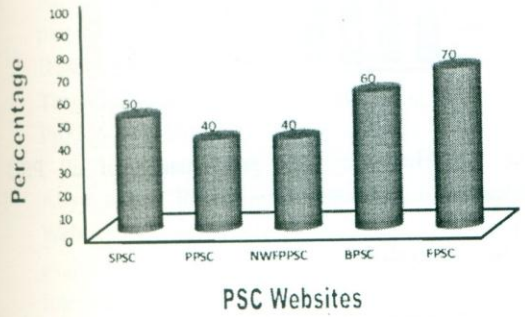


**Figure 6:** Results of Heuristic 6"Recognition rather than recall"

Figure 7 shows the results of all PSC websites. Five sub-categories of Heuristic 7 "Flexibility and efficiency of use" have been applied on all 05 PSC websites. The figure shows that SPSC website is the best one where 50% Heuristic is implemented and NWFPPSC got 30% results so ranked as the worst website.

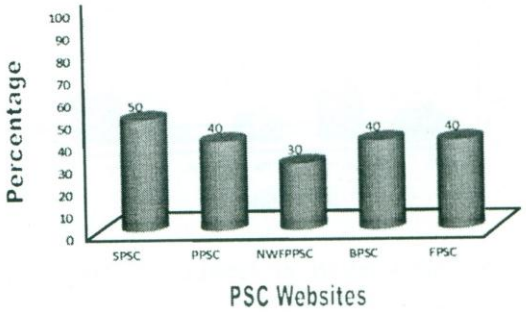


**Figure 7:** Results of Heuristic 7 "Flexibility and efficiency of use"

Figure 8 shows the results of all PSC websites. Five sub-categories of Heuristic 8 "Aesthetic and minimalist design" have been applied on all 05 PSC websites. The SPSC website is again on top by implementing 70% heuristic and on NWFPPSC website only 30% heuristics have implemented so it is ranked as the worst one.

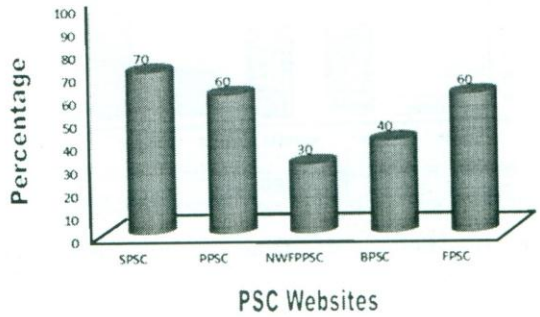


**Figure 8:** Results of Heuristic 8 "Aesthetic and minimalist design"

Figure 9 shows the results of all PSC websites. Five sub-categories of Heuristic 9 "Help users recognize, diagnose, and recover" have been applied on all 05 PSC websites. The figure shows that PPSC & FPSC websites are the best by implementing 20% heuristic whereas BPSC is the worst by having 0% heuristic implemented.

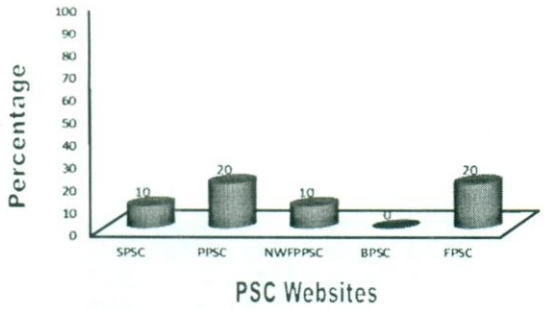


**Figure 9:** shows results of Heuristic 9 "Help users recognize, diagnose and recover"

Figure 10 shows the results of all PSC websites. Five sub-categories of Heuristic 10 "Help and documentation" have been applied on all 05 PSC websites. 90% Heuristic is implemented on FPSC website so ranked as the best one and 0% heuristic was implemented by SPSC hence ranked as the worst one.

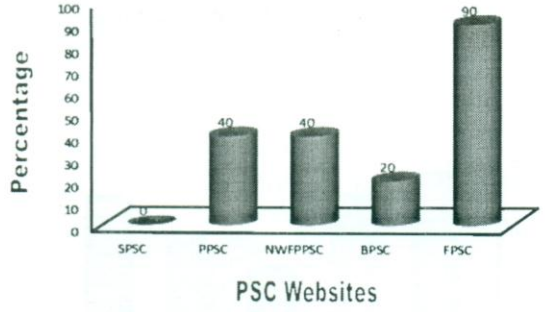


**Figure 10:** Results of Heuristic 10 "Help and documentation"

Figure 11 shows average result of 10 usability heuristics implemented on all five PSC websites. The figure clearly shows that FPSC website is the best one where all heuristics are implemented up to 56% level and NWFPPSC website has only implemented up to 35% of all heuristics hence ranked as the worst website.

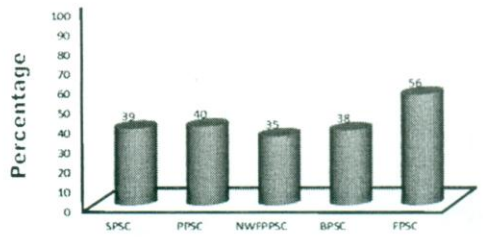


**Figure 11:** Website wise Heuristics Implemented on all PSC Websites

Figure 12 shows heuristic wise performance of all PSC websites. The figure clearly shows that heuristic 1 "Visibility of System Status" is the best one where it was implemented by all the five PSC websites up to 72% level and heuristic 5 "Error Prevention" was not implemented at all by all the websites so ranked as the worst heuristic.

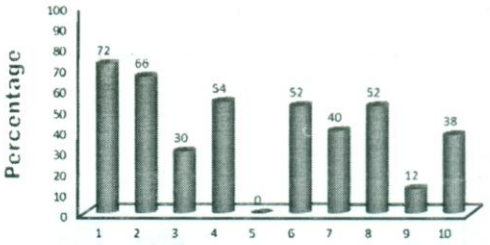


**Figure 12:** Heuristic wise performance of all PSC Websites

## 5. CONCLUSIONS

Heuristic evaluation is an easy tool to evaluate the websites and find the design problems in their interfaces. The results show that Heuristic 1 "Visibility of System Status" was implemented 72% by all websites hence ranked as the best. Heuristic 5 "Error Prevention" was implemented 0% so ranked as the worst in the context of these websites. FPSC website is the best website which has implemented 56% of all 10 heuristics (including sub-categories of the heuristics) and NWFPPSC is the worst website which has implemented 35% of all 10 heuristics (including sub-categories of the heuristics).

As a future work, these heuristics will be applied on other Pakistani e-government websites. Furthermore, an e-

government website will be developed from the scratch and usability tests and Heuristic Evaluations will be conducted and applied since its inception in order to develop a useful website for its end-users.

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# EXPERIMENTAL STUDY OF IN-PLANE SHEAR-WALLS CONNECTED BY BEAMS SUBJECTED TO LATERAL UDL

Mahmood Memon*, Tulsi Das Narwani**


## ABSTRACT

**Effect of lateral loads due to wind and earthquake becomes more pronounced with the increase in the height of a building. Almost all the design codes recommend certain procedures to calculate the equivalent static force on the building for which it is analysed and designed. However, there is little experimental evidence about the behaviour of such buildings subjected to various types of lateral loading. These buildings are more commonly analysed by continuous connection (laminar) method, the accuracy of which needs to be verified. Therefore a large scale RCC model representing a five storey building with a pair of planar cross shear-walls solely connected by beams subjected to equivalent static lateral uniformly distributed load was tested. The experimental study was carried out in terms of shear & bending of the beams, lateral deformation of the model, the crack pattern, strain in beams at joints and the mode of failure. The results of this experimental study are presented in this paper. Areas have been demarcated where more information and experimental behaviour of such buildings and proposals for further research have been put forward.**


**Keywords**: Equivalent static forces, Lateral loads, Shear & bending, Tall buildings.

## 1. INTRODUCTION

Modern tendency is to construct cross shear-walls and coupling beams to resist the transverse forces in addition to gravity loads as shown in figure 1 .The deflected shape of a typical connecting beam is shown in figure 2.In the recent past the system was simulated by equivalent wide columns as well. Although Rosman presented continuous connection method (called laminae), to the best of my knowledge it is not supported by experimental evidence. A lot of work has been done by different investigators regarding various features of coupled shear- walls. A new type of ductile coupling beam is proposed by Ding Dajun at el. (1997) to improve the ductility of coupling beams for earth quake loading and tests of 4-storey walls interconnected by coupling beams in three different constructions (monolithic beams, beams with a through slit and new-type beams) are conducted.

A macro model was developed by Ghobarah.A and Youssef. M (1999) to represent the behavior of structural walls, the model consist of nonlinear springs connected by linear beam elements and the model is capable of idealizing both shear and flexural behaviors of reinforced concrete structural walls. A new method of testing reinforced concrete coupling beams was developed by Kawn.A.K.H and Zhao. Z.Z (2002) which ensures equal rotations at the ends of the beam specimen and takes into account local deformation at the beam-wall joints. This method has been successfully applied to test typical reinforced concrete coupling beams with relatively small span/depth ratios. A new type of RCC shear-wall with concealed bracing is proposed and investigated by Cao W.L at el (2003). Four 1:3 scale medium-height specimens were designed and a detailed experimental investigation carried out. A theoretical model was proposed by Riyadh A at el. (2004) to predict the monotonic loading deformation behavior of diagonally reinforced coupling beams. The model is applied and compared to experimental tests that were conducted by several investigators. A nonlinear model was proposed by Xilin Lu and Yuntao Chen (2005) to simulate the behavior of coupled shear walls and experiments of coupled shear walls specimens with different sizes of coupling beams are carried out to verify the proposed model. A simple technique presented by Bhunia. D at el (2007) for the purpose of design to determine an appropriate level of yield moment capacity for the

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coupling beams. A simplified procedure proposed by Hindi & Riyadh (2007) to predict the monotonic behavior of diagonally reinforced coupling beams of shear walls.

The procedure yields a tri-linear monotonic force-displacement response up to failure. An experimental study was conducted by Su R.K.L. at el. (2007) to investigate the behaviour of deep coupling beams of span/depth ratio(1:7) fabricated according to the newly proposed plate reinforced composite(PRC) coupling beam design. Three PRC coupling beams of small span/depth ratio fabricated based on different approaches for load transfers between steel plates and reinforced concrete (RC) were tested under reversed cyclic loading. A large scaled model consisting of two planar walls solely connected by five beams was tested by Memon. M and Narwani. T.D (2008) to investigate behaviour of tall buildings subjected to lateral loading. It has been established the shear walls are more effective in resisting the lateral forces than columnar structure. The theory in its complete form called "Laminae Continuous Connection Method " to analyse high rise buildings subjected to lateral loads is presented by Rosman.R (1964). However experimental evidence regarding the validity of the theory is lacking. Therefore this experimental study was undertaken. Only one band of opening was considered.

## 2. STANDARD PROCEDURES

A common form of construction for multi-storey residential buildings consist of assemblies of shear-walls and connecting beams, in which the coupling of the cross-walls by the connecting beams results in more efficient structural system for resisting lateral forces. The cross-walls are employed as load bearing walls.

The shear-wall analysis subjected to lateral loads for finding out the bending moments and shear forces induced in the walls and connecting beams due to lateral forces is worked out by several investigators. Rosman proposed continuous connection method with several types of foundations, with one or two bays of openings for point load at the top of building and uniformly distributed load along the height of building.

## 3. CONTINUOUS CONNECTION METHOD

Rosman dealt with shear wall buildings with one or two bays of openings for dwelling purposes, the elements of such buildings are the piers and the connecting beams. The piers can be fixed in the same or separate foundations; the walls are often resolved with very stiff end beam with legged footings by hinged or rigid supports. The dimensions of each wall and width of opening are assumed to be constant through the height of building; the walls of one band of openings are not necessarily to be symmetric and walls of two bands of openings are assumed to be symmetric. To obtain the basic ideas of this system, replace the connecting beam by a continuous connection as shown in figure.3

The piers are fixed in the same foundation, in a rigid basement or in very stiff end beam

The equation for Integral shear force is given by

$$Q = G*\text{Sinh}(\alpha x) + (\gamma/\alpha^2)\,X \text{ for point load} \quad (1)$$

The same derivation for uniformly distributed load is applicable, and the equation for integral shear force:

$$Q = G*\text{Sinh}(\alpha X) - (2\beta/\alpha^4)*[\text{Cosh}(\alpha X)-1] + (\beta/\alpha^2)*X^2 \text{ for U.D.L} \quad (2)$$

Where X is the location measured from top of building, and the coefficient for wall containing single and double bands of opening are:

For one band of openings:

$$\alpha^2 = [(C^2/I_1 + I_2) + (1/A_1) + (1/A_2)]*12*I_P/L*L_W^3$$

$$\gamma = (P*C/I_1+I_2)*I_2*I_P/L*L_w^3$$

$$\beta = (0.5*w*C/I_1+I_2)*12*I_P/L*L_w$$

For two bands of openings:

$$\alpha^2 = [(2*C^2/2*I_1+I_2)+(1/A_1)]*12*I_P/L*L_W^3$$

$$\Upsilon = (P*C/2*I_1*I_2)*12*I_P/L*L_W^3$$

$$\beta = (0.5*w*C/2*I_1*I_2)*12*I_P/L*L_W^3$$

And the constant G for integral shear force, for both point load and uniformly distributed load are respectively:

$G = - \gamma / \alpha^3 * \text{Cosh}(\alpha H)$ for point Load

$G = [1 / \text{Cosh}(\alpha H)] * (2\beta/\alpha^3) [\{\text{Sinh}(\alpha H)/\alpha\} - H$
for U.D.L

## 4. INTERNAL FORCES

As we calculated the integral shear forces we have to obtain internal forces such as the shear forces of connecting beams and bending moment of the walls. The shear force of connecting beam v at level X is given by.

$v = G*[2*\text{Cosh}(\alpha X)*\text{Sinh}(\alpha L/2)]*(\gamma / \alpha^2)*L$ for point load (3)

$v = G*[2\text{cosh}(\alpha X) \sinh(\alpha L/2)] - 2\beta/\alpha^4*[2\sinh(\alpha X) \sinh(\alpha L/2)] + \beta/\alpha^*[2*X*L]$ for U.D.L (4)

The bending moment of the connecting beam can be found as

$M = 0.5*v*L_W$ (5)

The bending moment at any arbitrary cross-section of the walls of one or two bands of openings for point load is:

$M = (Q*C - P*X)*I_1/I_1 + I_2$ for one band of opening (6)

$M = 2*Q*C - P*X$ For two bands of opening (7)

And for uniformly distributed load the bending moment for one or two bands of openings are:

$M = Q*C - 0.5w*X^2$ for one band of opening (8)

$M = 2*Q*C - 0.5w*X^2$ for two bands of opening (9)

## 5. SIMPLIFIED THEORY

A simplified theory was presented by Barnard.P and Schwaighofer.J (1967). This theory is derived by using the laminae shear force diagram constructed by joining the laminae shear force at the top $v_T$ with the maximum laminae shear force $v_m$ at a location K from the top of building by a straight line then by joining the point of maximum shear force $v_m$ and zero at a location H from the top of building (at base) by a parabola as shown in figure 4. The laminae shear force at top $v_T$ and maximum laminae shear force $v_m$ at location K can be determined quickly for most common case of shear wall fixed at base with the single band of openings under uniformly distributed load.

The laminae shear force at top can be determined by

$v_T = Q / X$ (10)

The maximum laminae shear force can be determined by

$vm = (2\beta / \alpha 3)*(\alpha K - 1)$ (11)

Where

$K = \sinh^{-1}[\{\cosh(\alpha H) / \alpha H\} / \alpha]$

Where K is the location of maximum laminae shear force from the top of building

## 6. CURRENT STUDY

Apart from the point load at the top, one RCC model subjected to UDL representing transverse loading at each storey level was tested as shown in figure 5. The transverse loading was the major area of the experimental investigations .The complete dimensioned sketch of coupled shear walls with connecting beams is presented in figure 6.The stress distribution curves were plotted, shown in figure 7 & 8 both experimental as well as calculated ones. Experimental as well as values of Rosman and Simplified theory for the shears have also been compared shown in Table.5 (a).The integral and laminae shear have been calculated as shown in figure.9.From figure.6 it is quite apparent that the calculated stress values ( by Rosman method) are lower than that of experimental ones. The difference is considerably higher as we approach the top. However it can be said that Rosman method does not give the realistic picture because of the low level of stress than experimental values implying that the stresses are not realistic. On the contrary this method under-estimates the level of stresses. Similar is the case with Simplified theory as well shown in figure.7.This point needs further investigation. From these experimental comparisons it can be deduced that the analysis based on Rosman method as well as Simplified theory should not preferably be employed till such time that further investigations are carried out to prove or otherwise the validity of the methods. For the sake of completion of the theme the

deflection with respect to height has been presented in figure.10

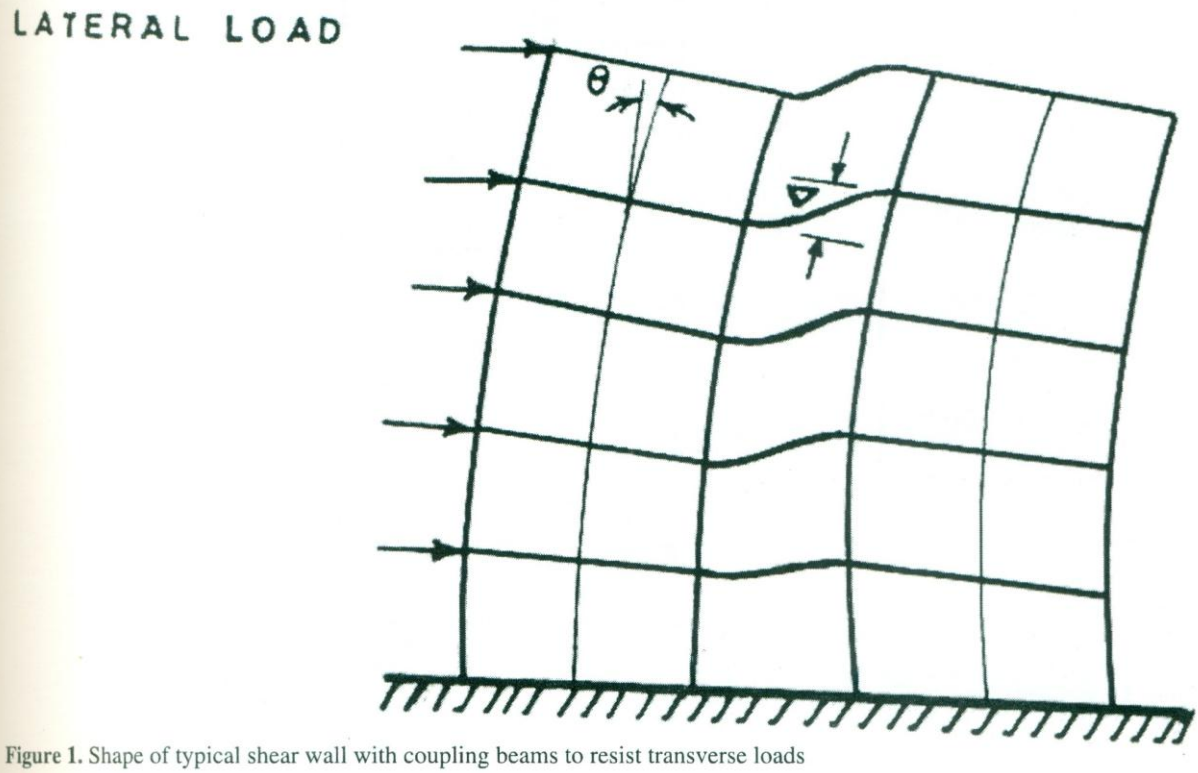


**Figure 1.** Shape of typical shear wall with coupling beams to resist transverse loads

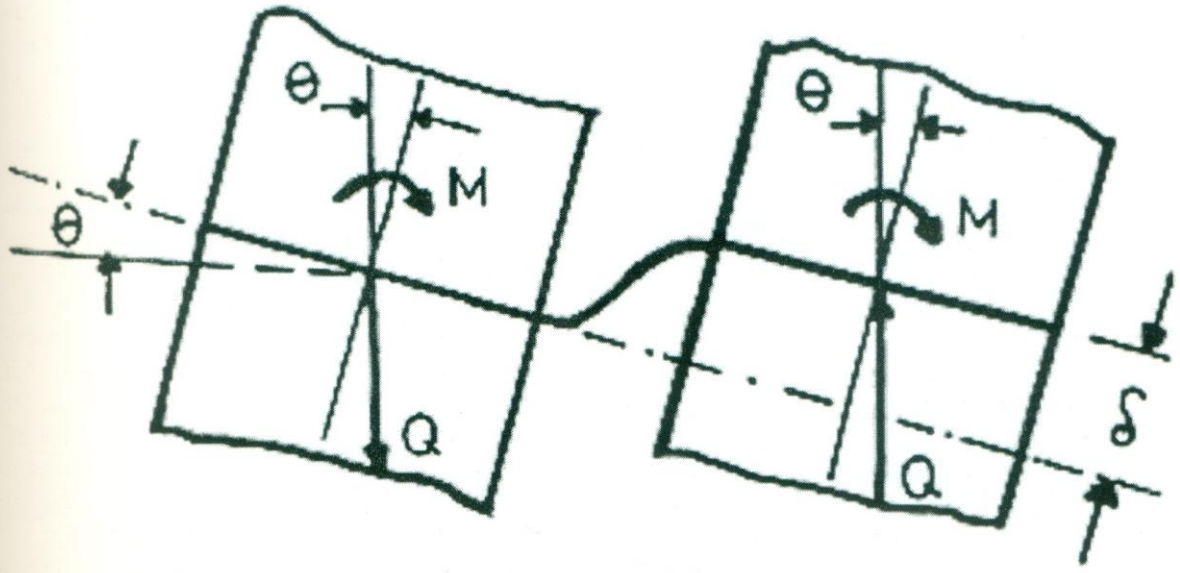


**Figure 2.** Deflected shape of the connecting beam in a shear wall structure

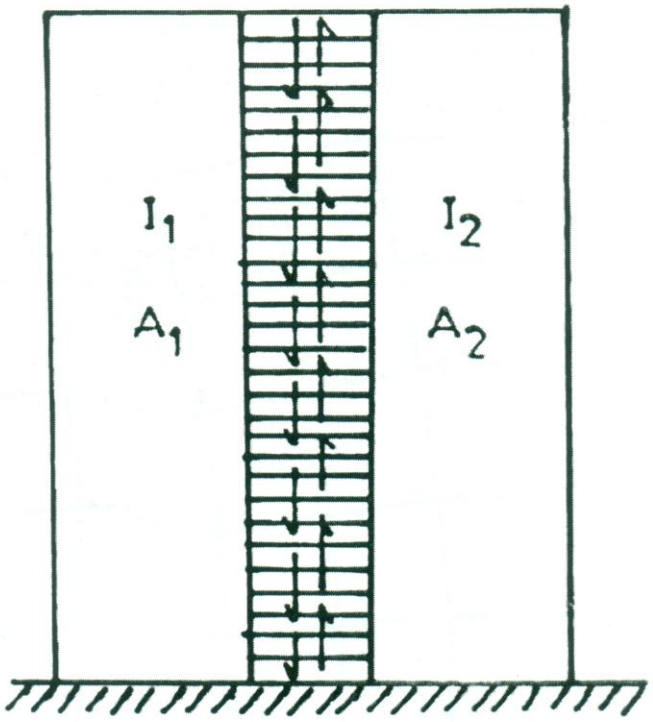


**Figure 3.** Shear wall with idealized continuous connection or laminae

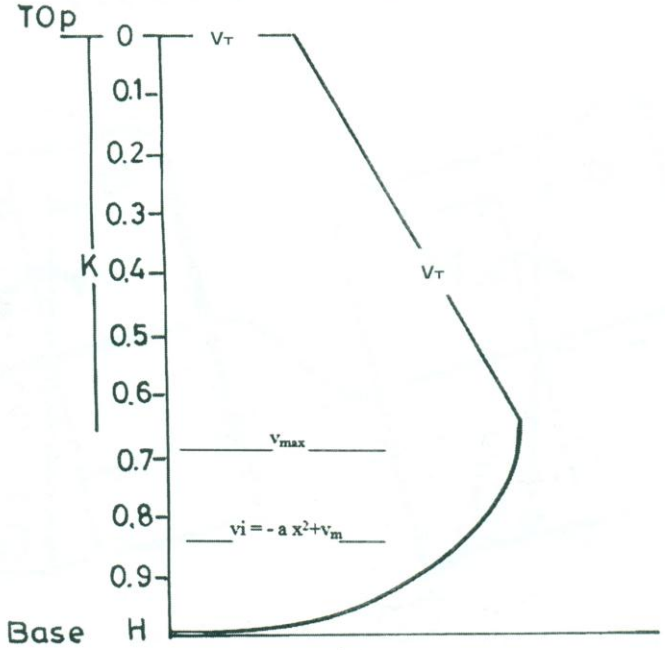


**Figure 4.** Laminae shear force diagram

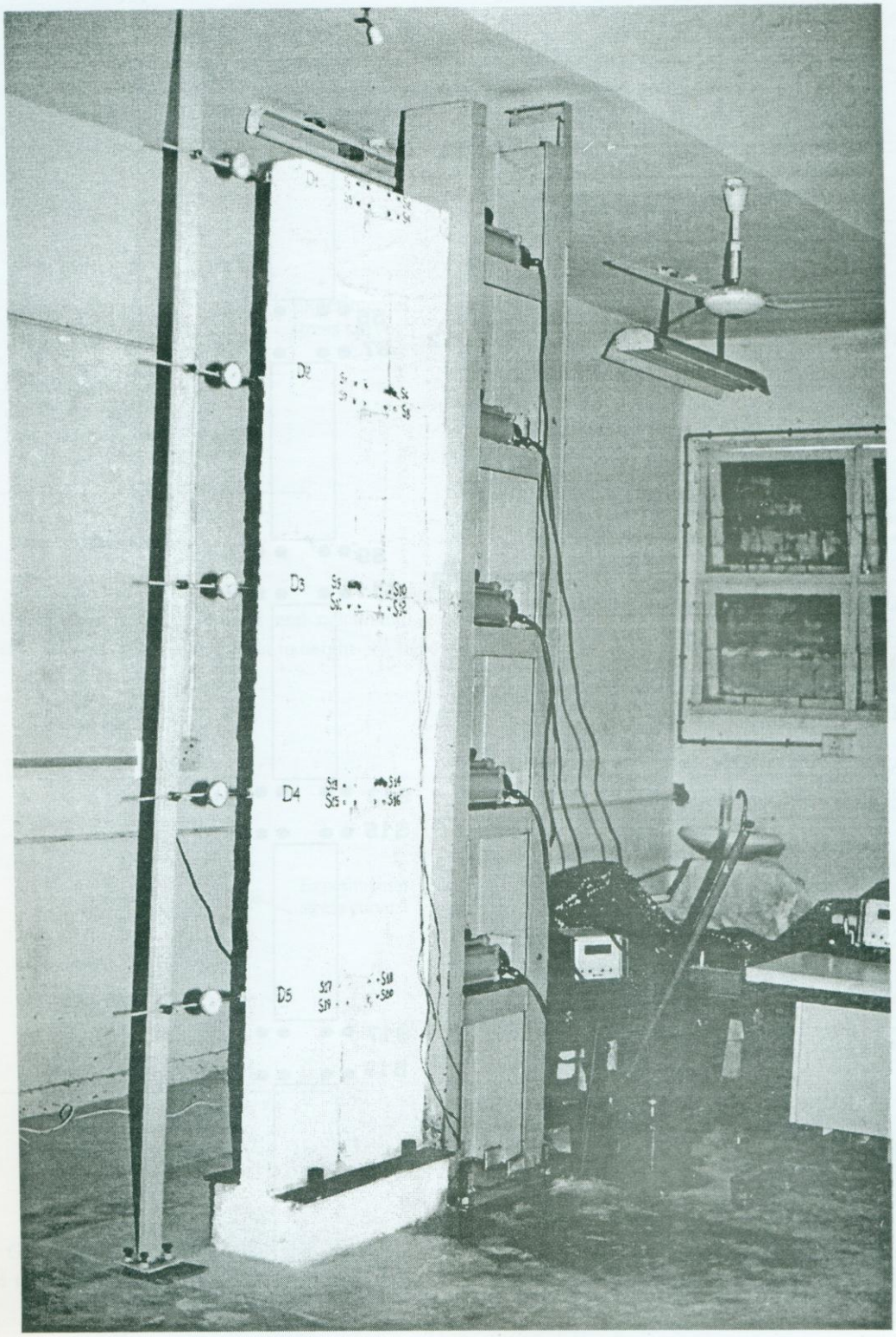


**Figure 5.** RCC model with testing arrangement

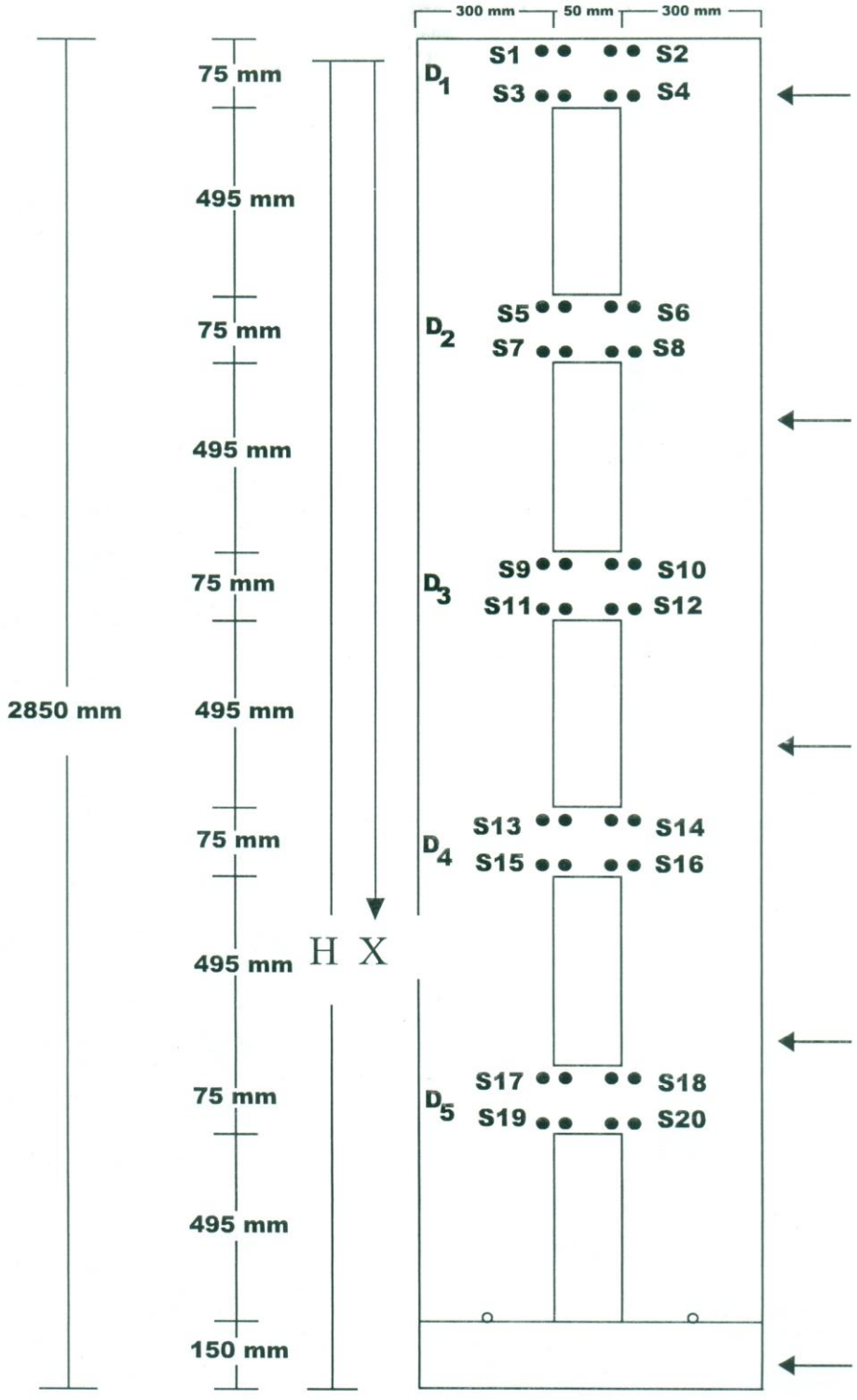


**Figure 6.** Sketch of Model with transverse loads

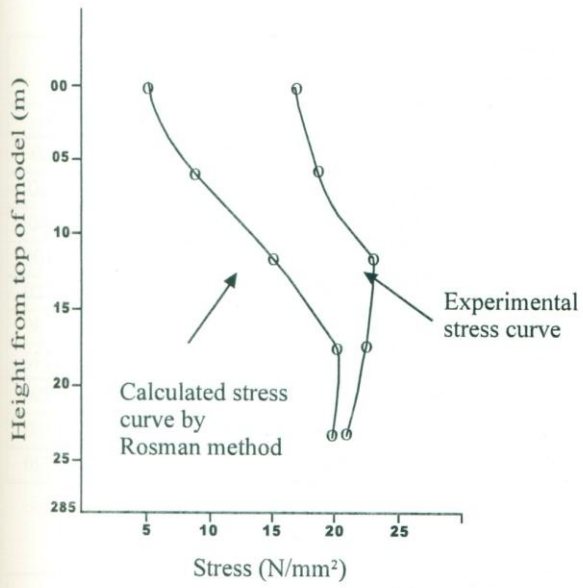


**Figure 7.** Graph showing experimental and calculated (Rosman method) stress curve with respect to height

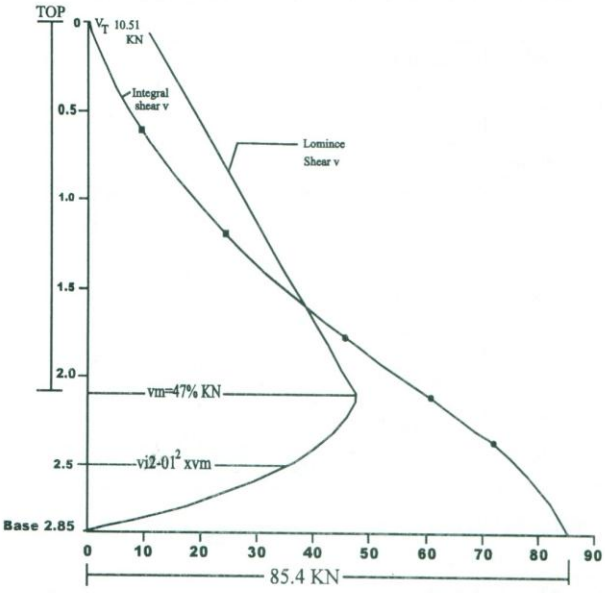


**Figure 9.** Graph showing Integral shear force and laminae shear force (Calculated).

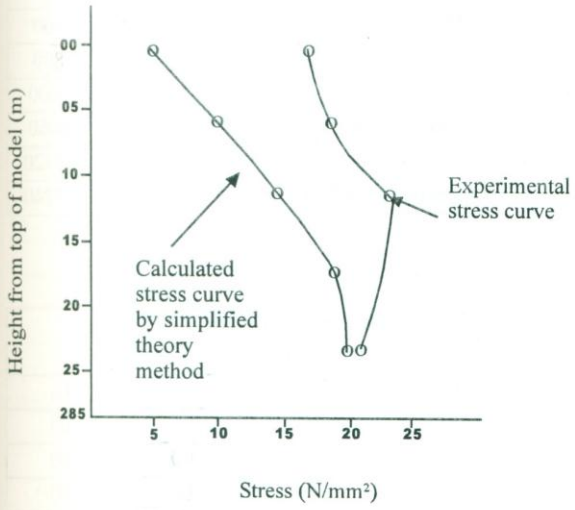


**Figure 8.** Graph showing experimental and calculated (Simplified theory method) stress curve with respect to height

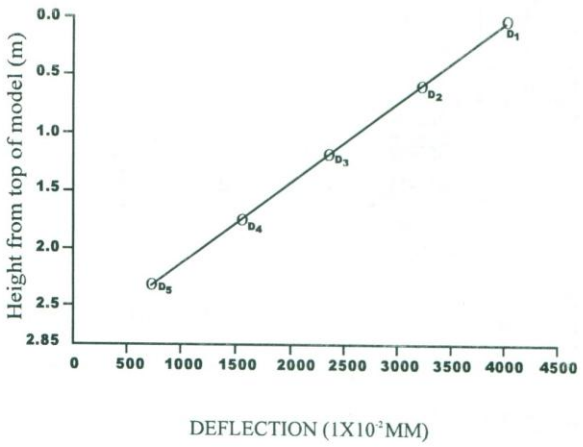


**Figure 10.** Graph showing experimental deflection versus height at ultimate lateral U.D.L along the height of model.

**Table 1:** Compressive strain in connecting beams in Model-IV

| S# | Load N | Compressive strain in connecting beams 1X10$^{-6}$ | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $S_2$ | $S_3$ | $S_6$ | $S_7$ | $S_{10}$ | $S_{11}$ | $S_{14}$ | $S_{15}$ | $S_{18}$ | $S_{19}$ |
| Initial | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 1 | 4600 | -20 | -40 | -100 | -80 | -120 | -100 | -100 | -80 | -40 | -60 |
| 2 | 9200 | -40 | -80 | -160 | -100 | -180 | -120 | -120 | -100 | -60 | -80 |
| 3 | 13800 | -60 | -100 | -180 | -140 | -200 | -160 | -160 | -120 | -80 | -100 |
| 4 | 18400 | -100 | -120 | -220 | -180 | -240 | -200 | -180 | -140 | -100 | -120 |
| 5 | 23000 | -120 | -160 | -240 | -200 | -260 | -220 | -200 | -180 | -120 | -140 |
| 6 | 27600 | -200 | -220 | -260 | -240 | -320 | -280 | -300 | -260 | -220 | -240 |
| 7 | 32200 | -240 | -260 | -320 | -280 | -400 | -340 | -360 | -320 | -280 | -300 |
| 8 | 36800 | -340 | -360 | -400 | -380 | -500 | -420 | -460 | -400 | -360 | -380 |
| 9 | 41400 | -560 | -600 | -640 | -620 | -820 | -760 | -780 | -740 | -700 | -720 |

**Table 2:** Tensile strain in connecting beams in Model-IV

| S# | Load N | Tensile strain in connecting beams 1X10$^{-6}$ | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $S_1$ | $S_4$ | $S_5$ | $S_8$ | $S_9$ | $S_{12}$ | $S_{13}$ | $S_{16}$ | $S_{17}$ | $S_{20}$ |
| Initial | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 1 | 4600 | 100 | 80 | 120 | 140 | 140 | 160 | 120 | 140 | 80 | 60 |
| 2 | 9200 | 120 | 100 | 140 | 220 | 200 | 180 | 140 | 160 | 120 | 100 |
| 3 | 13800 | 160 | 140 | 180 | 260 | 220 | 200 | 160 | 180 | 140 | 120 |
| 4 | 18400 | 180 | 160 | 220 | 300 | 260 | 220 | 180 | 200 | 160 | 160 |
| 5 | 23000 | 220 | 200 | 600 | 720 | 1200 | 1160 | 1080 | 1100 | 980 | 860 |
| 6 | 27600 | 9600 | 7800 | 9680 | 10000 | 9900 | 9480 | 8800 | 8960 | 7720 | 7600 |
| 7 | 32200 | 11220 | 9100 | 11300 | 11600 | 11540 | 11060 | 10380 | 10400 | 8900 | 8860 |
| 8 | 36800 | 21440 | 20740 | 25460 | 26300 | 28960 | 24560 | 23800 | 24420 | 20900 | 19120 |
| 9 | 41400 | 49560 | 48040 | 53760 | 54460 | 61240 | 54080 | 53820 | 51880 | 51120 | 47740 |

**Table 3:** Deflection of Model-IV

| S# | Load at each floor level N | Deflection of model 1x10$^{-2}$ mm | | | | |
|---|---|---|---|---|---|---|
| | | $D_1$ | $D_2$ | $D_3$ | $D_4$ | $D_5$ |
| Initial | 00 | 00 | 00 | 00 | 00 | 00 |
| 1 | 4600 | 13 | 00 | 00 | 00 | 00 |
| 2 | 9200 | 38 | 03 | 00 | 00 | 00 |
| 3 | 13800 | 70 | 24 | 08 | 00 | 00 |
| 4 | 18400 | 111 | 50 | 26 | 01 | 00 |
| 5 | 23000 | 148 | 101 | 61 | 18 | 00 |
| 6 | 27600 | 182 | 126 | 77 | 26 | 00 |
| 7 | 32200 | 924 | 830 | 532 | 282 | 154 |
| 8 | 36800 | 1907 | 1508 | 1085 | 631 | 306 |
| 9 | 41400 | 4040 | 3210 | 2350 | 1550 | 745 |

**Table 4:** Experimental Results of Compressive Strain & Deflection at various heights in Model-IV

| X-Distance from top of model m | Average compressive strain in connecting beams $1x10^{-6}$ | Deflection of model $1x10^{-2}$ mm |
|---|---|---|
| 0.0375 | 580 | 4040 |
| 0.6075 | 630 | 3210 |
| 1.1775 | 790 | 2350 |
| 1.7475 | 760 | 1550 |
| 2.3175 | 710 | 745 |

**Table 5(a):** Comparison of theoretical (Rosman and simplified theory method) with experimental results

| X-Distance from top of model m | Integral shear force (Rosman method) KN | Integral shear force (Simplified theory method) KN | Shear force of connecting beams (Rosman method) KN | Laminea shear force (simplified theory) KN | Shear force of connecting beams (Experimental determined) KN | Bending moment of connecting beams (Rosman method) N-m | Bending moment of connecting beams (Simplified theory) N-M | Bending moment of connecting beams (Experimental determined) N-m |
|---|---|---|---|---|---|---|---|---|
| 0.0375 | 0.394 | 0.407 | 6.60 | 11.18 | 71.5 | 495 | 470 | 5363 |
| 0.6075 | 8.30 | 9.58 | 10.93 | 21.44 | 77.81 | 820 | 920 | 5836 |
| 1.1775 | 22.95 | 24.85 | 18.57 | 31.70 | 97.53 | 1390 | 1360 | 7315 |
| 1.7475 | 45.27 | 45.84 | 25.39 | 41.95 | 93.84 | 1900 | 1793 | 7038 |
| 2.3175 | 72.12 | 71.81 | 24.86 | 43.38 | 87.65 | 1860 | 1850 | 6574 |

**Table 5 (b):** Comparison of theoretical (Rosman and simplified theory method with experimental results

| X-Distance from top of model m | Stress distributed in connecting beams (Rosman method) $N/mm^2$ | Stress distributed in connecting beams (Simplified theory method) $N/mm^2$ | Stress distributed in connecting beams ( Experimental determined ) $N/mm^2$ |
|---|---|---|---|
| 0.0375 | 5.28 | 5.01 | 17.0 |
| 0.6075 | 8.75 | 9.81 | 18.50 |
| 1.1775 | 14.83 | 14.51 | 23.19 |
| 1.7475 | 20.27 | 19.12 | 22.31 |
| 2.3175 | 19.84 | 19.73 | 20.84 |

## 7. GENERAL DISCUSSIONS

From the above behaviour of experimental study several points have come to the forefront as follows

1. From the Table.5 (b) it is observed that the experimental values and that of calculated stress values (Rosman method) are in the ratio of 3.33 at top. Similarly substantial reduction occurs showing that these values are in the ratio of 2.11 at the 4th storey level. At 3rd storey this ratio is 1.56. At 2nd storey level this is 1.10 and the ratio becomes 1.05 at first storey level.

2. For Simplified theory these values become 3.4, 1.88, 1.6, 1.16 and1.06 respectively. Thus it is obvious that the ratio is not uniform throughout the height therefore an appropriate form of equations should be developed to estimate the more realistic values and for this purpose a model with more storeys(height)

Where; F (factor) varies from 3.0 to 1.0 i-e 3.0 at top and 1.0 at bottom.

## 8. CONCLUSIONS

1) Rosman method as well as Simplified theory should not preferably be employed till further investigations are carried out.

2) The shear force of connecting beam may be calculated from:

$$v = F[G\{2\cosh(\alpha X)\sinh(\alpha L/2)\}- 2\beta/\alpha^4\{2\sinh(\alpha X)\sinh(\alpha l/2)\}+\beta/\alpha^2(2XL)]$$

where F (factor) varies from 3.0 to 1.0 i-e 3.0 at top and 1.0 at bottom.

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