

*Full Length Research Paper*

# Visualization RCD (reinforced concrete design) table advisor for decision support activity

L. O. Yusuf<sup>1\*</sup>, O. Folorunso<sup>1</sup>, A. T. Akinwale<sup>1</sup> and I. A. Adejumobi<sup>2</sup>

<sup>1</sup>Department of Computer Science, University of Agriculture, Abeokuta, Nigeria.

<sup>2</sup>Department of Electrical and Electronics Engineering, University of Agriculture, Abeokuta, Nigeria.

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Reinforced concrete design (RCD) activity requires the services of design table to pick bar sizes and area of specific bar groups. This allow reinforced concrete (RC) designers to use their intuition to pick the right bar size for detailing of RC Structures which virtually enhance reliable and satisfactory answers to RCD problems. With the advent of computer with its powerful memory, most RCD software available automatically generates Steel Properties thus, jeopardising user's contribution in terms of their perception. RCD Tables are conventionally small but not limited in use. By the skilful and innovative integration of available concepts and techniques, the power of the RCD Tables are enhanced to check for deflection, minimum and maximum area of steel, and display alert to users. Visualization RCD Table interface was designed as a dialog box. Simply Supported Reinforced Concrete Beam Structure (SSRCBS) tool was modified to accommodate the new tool. Statistical analysis revealed that the significance of time was borderline between SSRCBS tool and the modified tool. It was also found that as the tasks became more complex, the modified tool advantage increases in terms of task-by-task satisfaction and users understanding of the logic behind RCD.

**Key words:** RCD visualization, RC, PDAs, SSRCBS, visRCD table advisor, DSS.

## INTRODUCTION

Most people do not like change because they do not like being changed. However Civil Engineers are not exempted. RCD professionals make their decisions based on what the facts means to them, not on the facts themselves hence, majority of RC Designers still prefer the manual ways of implementing RCD. Lack of trust in the underlying codes that make RCD software is also a major issue. Many of this software if not all, take control of user's perception at the stage of choosing reinforcement bars for design. For example, a computer program may generate 3nos. High yield 12 mm diameter bars whereas user may prefer 2nos. High yield 16 mm diameter bar. Another reason why RC Designer were not so enthusiastic with established software is because the new technology is usually a diversification from their old way of thinking and they believe it will be difficult to cope

with either the level or pace of the change. The intention is to simulate the old ways RC designer works without compromising speed, accuracy and efficiency so as to persuade them into accepting the new technology. The output generated will also simulate a typical calculation sheet with all necessary arithmetic procedures and results. We are of the opinion that "good ideas are not adopted automatically; they must be driven into practice with courageous patience". The traditional approach to RCD tools uses visualization as the first and last steps of a process; it fails to take advantage of visualization within the process.

The visRCD Table Advisor tool-kit integrates visualization into every step within the RCD process. The user will have access to pop-in visualization visRCD table advisor dialog box at every step of the RCD process where steel is required. The combination of plentiful memory and interactive computational power enables RCD table to become more powerful, while handheld devices such as PDAs have the potential to render them mobile and permit immediacy of use. We Design RCD

\*Corresponding author. E-mail: truevisionconsulting@yahoo.com. Tel: +234 803 403 7098.

table interface as a dialog box which can be borrowed and re-used by other designers without changing the underlining code. It can also be configured as widget for use on the desktop and over the internet. We acknowledge the part played by existing knowledge in the manual use of RCD tables. Much of the groundwork for this design was laid by an earlier work by Yusuf et al. (2009). They visualized a simple beam by automatically generating reinforcement properties for the purpose of beam detailing. We believe user's perception has been suppressed by not allowing them to use their intuition to make their choice from the steel table. The work is therefore modified to incorporate visRCD table advisor dialog box. The Visualization RCD (visRCD) Table Advisor tool-kit integrates visualization into every step within the RCD process by using information visualization approach to check and mitigate against failure. Our major contribution here is the integration of a host of techniques to create a novel application that is both usable and useful in any RCD domain.

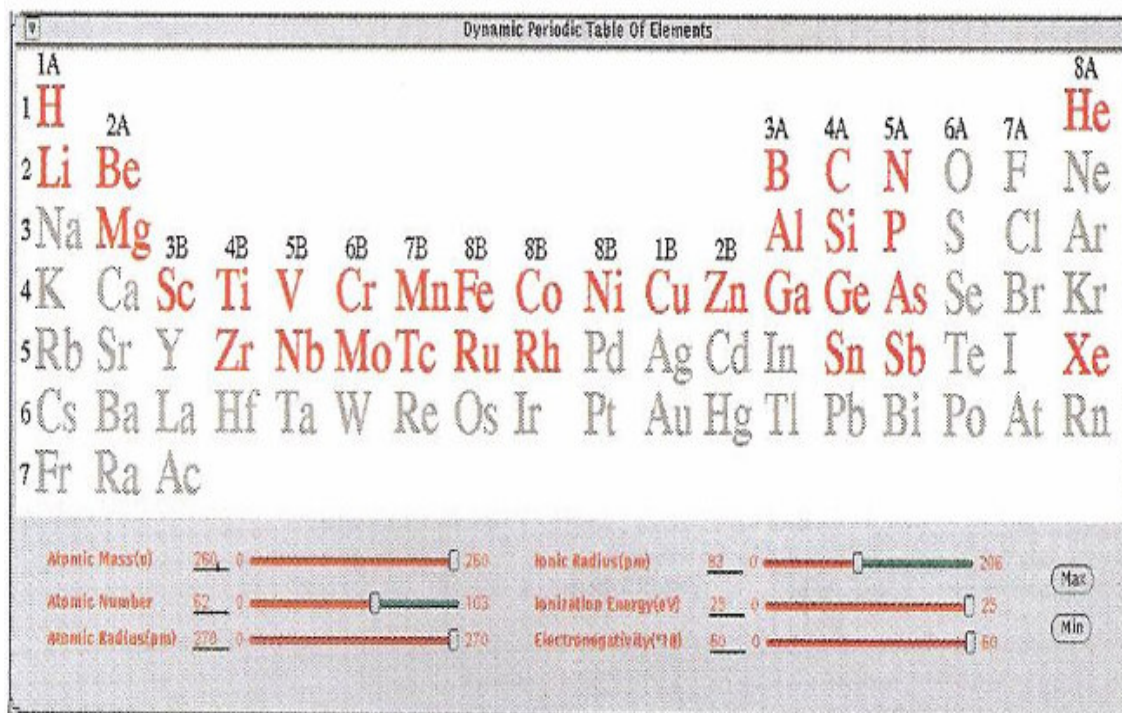
## BACKGROUND

It is appropriate to examine earlier work that is relevant to the development of an interactive RCD table. The periodic table, created by Mendeleev, is an important diagram in the development of chemistry. In the periodic table, the elements are arranged by the number of protons and atomic nucleus. Figure 1 show information visualization based on the periodic table (Ahlberg et al., 1992). The user can set sliders that control the elements in the table which will be highlighted. For example, the user can indicate interest in ionic radii between 93 and 206 and instantly those values will be highlighted on the table. The sliders can be used to find specific values or to see the trends with the change of some variable. Since the periodic table is already an excellent visual organizer of chemical properties, adding dynamically created patterns on the table is effective.

The first proposal for a fisheye calendar appeared in Spence and Apperley's original 1982 paper proposing the concept of distortion. A rudimentary illustration presented in 1980 (Imperial College) purely for concept demonstration, exploited both X-distortion and Y-distortion, but its implementation was severely limited by available technology. Later, Furnas (1986) described a textual program in which clicking on an individual day caused the amount of space allocated to that day to be increased. Impressive for its time, it did not support graphical representations or searching and it did not have widgets to control which and how many weeks to display. Furthermore, it was not designed with small displays in mind. Later, Sutton and Spence (1988) described a means of suppressing detail to provide space by employing the metaphor of sliding tectonic plates; 'plates' containing the full detail of a day could be moved to

provide more space for a particular day or collection of days (e.g. a week). Since a calendar is essentially a collection of tables, the potential offered by the table lens (Rao and Card, 1994) must be considered. However, it is principally designed to support one item per cell rather than the multiple items demanded by calendars. Other early work included the first visual representation of a calendar on a small display (Plaisant and Shneiderman, 1992) and the cascade of calendar components due to Mackinlay et al. (1994). The latter is not suitable for small display devices, though it has a fisheye-like quality. The developers of EZChooser (Robert, 2007) paid attention to two visualization techniques which allow users to form better cognitive models of the decision space, they are: dynamic queries and the attribute explorer.

Colin, 2004 believes that the best visualizations are not static images, but fluid dynamic objects that respond to the need for a different view or for more detailed information. In some cases, the visualization can be an interface to a simulation of complex problem. The visualization, combined with the simulation, can create a powerful cognitive augmentation like the one created for our modified tool. He also observed that an emerging view of human-computer interaction considers the human and the computer together as problem-solving system. He noted that visualization is a two-way interface, although highly asymmetric, with far higher bandwidth communication from the machine to the human than in the other direction. He advised that the cognitive support systems be constructed such that they are semiautomatic, with only occasional nudges required from users to steer them in a desired direction and the high-bandwidth visualization channel should be used to deliver the results of modeling exercises and searches. Shneiderman, 1992 believe dynamic queries are lively new direction for database querying. He noted that many problems that are difficult to deal with using a keyword-oriented command language become tractable with dynamic queries. He observed that computers are now fast enough to apply a direct manipulation approach on modest-sized problems and still ensure an update time under 100 ms. The challenge now is to broaden the spectrum of applications by improving user-interface design, search speed, and data compression. Mack and Rock (1998) found that we are blind to many changes in our environment and that some visual events are more likely to cause us to change attention more than others. Jonides (1981) studies ways of moving a subject's attention from one part of a display to another. He looked at two different ways, which are sometimes called pull cues and push cues. In a pull cue, a new object appearing in the scene pulls attention towards it while in a push cue, a symbol in the display, such as an arrow, tells someone where a new pattern is to appear. It appears to take only about 100 m/s to shift attention based on a pull cue but can take between 200 and 400 m/s to shift attention based on a push cue. Visual



**Figure 1.** The chemical table of elements makes a natural visual display for information on chemical properties. Chemicals matching the query are shown in red. Runs and jumps are apparent. (Culled from Readings in Information Visualization; Using Vision To Think p. 8)

attention is not strictly tied to eye movements. Although attending to some particular part of display often involves an eye movement, and there are also attention processes operating within each fixation. The studies of Treisman and Gormican (1988) showed that we process simple visual objects serially at a rate of about one every 40 - 50 m/s, because each fixation typically will last for 100 - 300 m/s. It means that our visual systems process two to six objects within each fixation before we move our eyes to attend visually to some other region. Attention however is also not limited to specific locations of a screen. We can, for example, choose to attend to a particular pattern that is a component of another pattern, even though the pattern overlaps spatially (Rock and Gutman, 1981). We can also choose to attend to a particular attribute if it is pre-attentively distinct (Treisman, 1985). The selectivity of attention is by no means perfect. Even though we may wish to focus on one aspect of a display, other information is also processed, apparently to quite a high level. The well known Stroop effect illustrates this (Stroop, 1935). Given an optimal state of readiness, with a finger poised over a button, a person can react to a simple visual signal in about 130 m/s (Kohlberg, 1971). If the signals are very infrequent, the time can be considerably longer. Warrick et al. (1964) found reaction times as long as 700 m/s under conditions such that there could be as much as two days between signals. It has been discovered that reaction times can be modeled

by a simple rule called the Hick-Hyman law for choice reaction time (Hyman, 1953). According to this law,  $\text{Reaction time} = a + b \log_2(C)$ . Where  $C$  is the number of choices and  $a$  and  $b$  are empirically determined constants. The expression  $\log_2(C)$  represents the amount of information processed by the human operator, expressed in bits of information.

Psychologists have conducted extensive experiments that involve changing the relationship between eye and hand. If a prism is used to laterally displace what is seen relative to what is felt, people can adapt in minutes or even seconds (Welch and Cohen, 1991). This is like using a mouse that is laterally displaced from the screen cursor being controlled. On the other hand, if people are asked to view the world inverted with a mirror, it can take weeks of adaptations for them to learn to operate in an upside-down world (Harris, 1965). Snyder and Pronko (1952) had subjects wear inverting prisms continuously for a month. At the end of this period, reaching behaviours seemed error-free, but the world still seemed upside-down. This suggests that if we want to achieve good eye-hand coordination in an interface, we do not need to worry too much about matching hand translation with virtual object translation, but we should worry about matching the axis or rotation. In the Go-Go Gadget technique (named after the cartoon character, Inspector Gadget), the user's virtual hand is stretched out far beyond his or her actual hand position to allow for

manipulation of objects at a distance (Poupyrev et al., 1996). Studies by Ramachandran (1999) provided interesting evidence that even under extreme distortions people may come to act as if a virtual hand is their own, particularly if touch is stimulated. Memory provides the framework that underlies active cognition. Working memory is not a single system; rather, it has a number of interlinked but separate components. There are separate systems for processing auditory and visual information, as well as subsystems for body movements and verbal output (Thomas et al., 1999). There may be additional stores for sequences of cognitive instructions and for motor control of the body. Kieras and Meyer (1997), for example, proposed an amodal control memory, containing other miscellaneous information. A similar control structure is called the central executive in Baddeley and Hitch's model (1974).

Fady (2008) developed program for analysis and design of beams up to three spans, upon the input of beam parameters, the program automatically fix bar sizes. This program was created using the relatively new Action script language. An approach to visualizing the detection of failure in reinforced concrete beam structure under various types of loadings was described by Yusuf et al. (2009). They used Model-View-Controller concept to implement visualization exploratory tool that assists the RCD designers in understanding the actual behaviour of the RCD Beam algorithms of choice and also in evaluating the performance quality of the algorithms. Their analysis led to a development model for SSRCBS tool. The tool automatically generates reinforcement properties without taking user's contribution (at this stage) into consideration. The tool is therefore modified to address the observed lapses. They also created visRCD Beam interface as input visualization environment while they borrowed and enhanced AutoCAD interface as output visualization environment. We have added visRCD Beam Table Advisor as intermediate visualization environment. Ben Shneiderman coined what he calls a "mantra" to guide visual information-seeking behaviour and the interfaces that support it: "Overview first, zooms and filters, then details on demand," (Shneiderman, 1998). But in RCD visualization we are just as likely to see an interesting detail zoomed out to get the details of the original object of interest. The important point is that a good computer-based visualization is an interface that can support all of these activities. Ideally, every RCD data object on the screen is active and not just a blob of colour on the screen. It is capable of displaying more information as needed, disappearing when not needed, and accepting user commands to help with the thinking process. Kirsh and Maglio (1994) define a class of epistemic actions as activities whereby someone hopes to better understand or perceive a problem. At the highest level is a problem-solving loop through which the analyst forms hypotheses about the data and refines them through an augmented RCD visualization process.

The process may be repeated through multiple RCD visualization cycles. As new data is added, the problem is reformulated, possible solutions are identified, and the RCD visualization is revised or replaced. Sometimes the RCD Table Advisor visualization may act as a critical externalization of the problem, forming a crucial extension of the cognitive process.

## **DSS FOR VISRCD TABLE ADVISOR**

Decision support systems (DSS) are a specific class of computerized information system that supports business and organizational decision-making activities. A properly designed DSS is an interactive software-based system intended to help decision makers compile useful information from raw data, documents, personal knowledge, and/or business models to identify and solve problems and make sound decisions or construct strategies from analysis (Power, 2007). It is important to note that although computers and artificial intelligence is at work or in play with data, it is ultimately up to humans to execute these strategies or comprehend the data into a usable hypothesis. Decision support systems have a definite structure in RCD, but in reality, the data and decisions that are based on it are fluid and constantly changing. According to Wikipedia (2010), the three fundamental components of DSS architecture are: The database (or knowledge base), the model (that is, the decision context and user criteria) and the user interface. The users themselves are also important components of the architecture.

One of the DSS models available is with the relationship of the user in mind. This model takes into consideration passive, active and cooperative DSS models. Decision support systems that just collect data and organize it effectively are usually called passive models, they do not suggest a specific decision, and they only reveal the data. An active decision support system actually processes data and explicitly shows solutions based upon that data. While there are many systems that are able to be active, many organizations would be hard pressed to put all their faith into a computer model without any human intervention. A cooperative decision support system is when data is collected, analyzed and then is provided to a human component which then can help the system revise or refine it. It means that both a human component and computer component work together to come up with the best solution, the RCD Table Advisor fall into this last category. While the above DSS model takes the relationship of the user in mind, another popular DSS model takes into consideration the mode of assistance as the underlying basis of the DSS model. This includes the Model Driven DSS, Communications Driven DSS, Data Driven DSS, Document Driven DSS, and Knowledge Driven DSS. Model Driven DSS is when decision makers use

statistical, simulations or financial models to come up with a solution or strategy. Keep in mind that these decisions are based on models; however they do not have to be overwhelming data intensive. A communications driven DSS models is when many collaborators work together to come up with a series of decisions to set in motion a solution or strategy. This communications driven DSS model can be in an office environment or on the web. A data driven DSS model (which is appropriate for the visRCD Table Advisor) puts its emphasis on collected data that is then manipulated to fit the decision maker's needs. This data can be internal, external and in a variety of formats. A Document Driven DSS model uses documents in a variety of data types such a text documents, spreadsheets and database records to come up with decisions as well as further manipulate the information to refine strategies. A knowledge driven DSS model uses special rules stored in a computer or used by a human to determine whether a decision should be made. These rules or facts are used in order to make a decision.

The benefits derived from RCD table advisor as decision support activity are many, they includes: improved user's efficiency, expedites problem solving (speed up the process of serviceability limit state test with immediate corrections/amendments), Facilitates interpersonal communication with RCD, Promotes learning or training, Increases user's control of design process, Generates new evidence in support of a decision for RCD process, Creates a competitive advantage over existing tools which automatically generate RCD properties thus not respecting user's judgements, encourages exploration and discovery on the part of the RCD users who are the decision maker, Reveals new approaches to thinking about the problem space of RCD. Helps automate the managerial processes for RCD.

## METHODOLOGY

VizRCD Table Advisor is designed as a dynamic query which continuously updates search results as users select buttons to ask simple or complex questions of fact or to find patterns or exceptions relating to RCD. To accomplish this, the dynamic-query approach applies the principles of direct manipulation to the visRCD table Advisor environment through:

- Visual presentation of the query's components.
- Visual presentation of results.
- Rapid incremental and reversible control of the query.
- Selection by pointing, not typing; and
- Immediate and continuous feed back.

The ultimate result of any RCD is the design moment and design shear stress, once design moment is known; area of steel for design can be calculated based on the following procedure:

- Locate the various beams positions, spans and supports.
- Estimate beam sizes using guidelines suggested by Oyenuga, 2007

Beam dimensions are specified as depth x breadth and the depth is inclusive of the slab depth (in case of T- or L-beam. The depth

chosen should not violate the basic span/effective depth ratio as a measure for control of deflection.

- Estimate the load on the beam based on beam own load, slab load on the beam (if any), wall load on the beam (if any) and roof load on the beam (if any).

- Analyze the beam using any known structural analysis approach to obtain

$$\text{Ultimate\_Load} = 1.4 \times \text{Dead\_Load} + 1.6 \times \text{Live\_load}$$

Obtain Design\_Moment from Ultimate\_Load and Beam\_Span

$$\text{Obtain } k\_value \text{ from } k\_value = \text{Design\_Moment} / (\text{Design\_Cube\_Strength} \times \text{Breadth} \times \text{Depth}^2)$$

When  $k\_value \leq 0.156$ , design beam as singly reinforced otherwise design as doubly reinforced section

- Calculate area of steel reinforcement required:

$$\text{When } k\_value \leq 0.156, \text{la} = 0.5 + \sqrt{0.25 - k\_value/0.9}, \text{ and steel area is calculated from } A_s = \text{Design\_Moment} / (0.95 \times \text{Steel\_Strength} \times \text{la} \times \text{Depth}) \text{ mm}^2$$

When  $k\_value > 0.156$ , the compression reinforcement is calculated from:

$$\text{Mu} = 0.156 \times \text{Design\_Cube\_Strength} \times \text{Breadth} \times \text{Depth}^2$$

$$A_c = (\text{Design\_Moment} - \text{Mu}) / (0.95 \times \text{Steel\_Strength} \times (\text{Depth} - \text{Cover}))$$

$$\text{And } A_s = A_c + (0.156 \times \text{Design\_Cube\_Strength} \times \text{Breadth} \times \text{Depth}^2) / (0.95 \times \text{Steel\_Strength} \times (0.775 \times \text{Depth}))$$

Note that  $Z_u = 0.775d$  when  $k\_value = 0.156$

Choose reinforcements from the steel table in Table 1.

The steel table in Table 1 is generated from the following formular

$$\text{Area of Steel} = \text{Number of Bar} \times 3.142 \times \text{Bar Size}^2 / 4$$

For example; when Bar Size = 16 and Number of Bars = 7

$$\text{Area of Steel} = 7 \times 3.142 \times 16^2 / 4 = 1407.43 = 1470 \text{ (to the nearest integer)}$$

- Check for Minimum and maximum area of reinforcement.
- Check for deflection.
- Design for shear and pick shear reinforcement from the steel table in Table 2 by calculating shear,  $v = V/bd$  where V is the Shear Force, b is the Beam width and d is the beam depth. Determine the permissible shear stress,  $v_c$  from  $v_c = 0.632(100A_s/b_v d)^{1/3}(400/d)^{1/4}$ .  
 $100A_s/b_v d \leq 3.00$ .  
 $400/d \leq 1.00$ .

If Concrete Grade ( $f_{cu}$ ) is between 25 and 40 use  $v_c = v_c(f_{cu}/25)^{1/3}$   
Design stirrups as follows:

When  $v < 0.5v_c$  provide minimum links

When  $0.5v_c < v < (v_c + 0.4)$  provide links with spacing calculated from  $s_v = 0.95A_{sv}f_{yv}/0.4b$

When  $v > 0.8\sqrt{f_{cu}}$  or  $5.0N/mm^2$  provide links with spacing calculated from  $s_v = 0.95A_{sv}f_{yv}/(b_f(v - v_c))$

When  $v > 0.8\sqrt{f_{cu}}$  or  $5.0N/mm^2$  increase beam depth and repeat the design from reinforcement areas determination

## UNIFIED MODEL LANGUAGE (UML) FOR RCD BEAM

We implement UML for RCD beam using yEd Graph Editor Tool (Figure 2a and b).The tool is a freeware downloadable at <http://www.yWorks.com>. The UML for RCD shows different types of beams for analysis which inherits their properties from RCD properties interface. There are eight loads possibilities on each beam span which can be combined in sixty-four ways on a single

**Table 1.** Sectional areas of groups of bars (mm<sup>2</sup>).

Bar size (mm)	Number of bars									
	1	2	3	4	5	6	7	8	9	10
6	28.3	56.6	84.9	113	142	170	198	226	255	283
8	50.3	101	151	201	252	302	352	402	453	503
10	78.5	157	236	314	393	471	550	628	707	785
12	113	226	339	452	566	679	792	905	1020	1130
16	201	402	603	804	1010	1210	1410	1610	1810	2010
20	314	628	943	1260	1570	1890	2200	2510	2830	3140
25	491	982	1470	1960	2450	2950	3440	3930	4420	4910
32	804	1610	2410	3220	4020	4830	5630	6430	7240	8040
40	1260	2510	3770	5030	6280	7540	8800	10100	11300	12600

Culled from Reinforced Concrete design by Bill et al. (2007).

**Table 2.** Asv/s for varying stirrup diameter and spacing

Stirrup diameter (mm)	Stirrup spacing (mm)										
	85	90	100	125	150	175	200	225	250	275	300
8	1.183	1.118	1.006	0.805	0.671	0.575	0.503	0.447	0.402	0.366	0.335
10	1.847	1.744	1.57	1.256	1.047	0.897	0.785	0.698	0.628	0.571	0.523
12	2.659	2.511	2.26	1.808	1.507	1.291	1.13	1.004	0.904	0.822	0.753
16	4.729	4.467	4.02	3.216	2.68	2.297	2.01	1.787	1.608	1.462	1.34

Culled from Reinforced Concrete design by Bill et al. (2007).

span. The RCD properties interface and Load Beam interface worked together and they are always activated simultaneously to get user's input. The manoeuvring for drawing the bending moment and shear diagram using AutoCAD (2009) Active X control is done through the RCD Engine class which is revealed in AutoCAD Interface. The RCD Engine class also activate RCD Table advisor for design and detailing purpose.

## IMPLEMENTATION

We design the RCD visualization environment not just as a static or a 3D virtual environment that we can walk through and inspect like a museum full of statues, but something that allows us to drill down and find more data about anything that seems important to the RCD process which will help us during detailing process. The dynamic query approach we have adopted empowers users to perform far more complex searches by using visual search strategies. The enthusiasm RCD analysts have for dynamic queries emanates from the sense of control they gain. They quickly perceive patterns in data, fly through data by clicking buttons and rapidly generate new queries based on what they discover through incidental learning. Interactive RCD visualization is a process made up of a number of interlocking feedback loops that fall into three broad classes. At the lowest level is the data manipulation loop, through which objects are selected and moved using the basic skills of eye-hand coordination. Delay of even a fraction of a second in this interaction cycle can seriously disrupt the performance of higher-level tasks in RCD visualization. At an intermediate level is an exploration and navigation loop, through which an analyst finds his or her way in a large visual RCD data space. But exploration of RCD data process can be generalized to more abstract searching operations.

In order to understand how visRCD Table Advisor works, we modified the work of Yusuf et al. (2009), by incorporating visRCD Table Advisor into SSRCBS. Knife Edge Load of 10 kN, Distributed Load of 15 kN and Beam span length of 5 m were entered into the visRCD Beam interface which produced the bending moment diagram within the AutoCAD 2009 interface as shown in Figure 3. When 'Design for Main Bar' sub menu is activated from option menu, the visRCD Table Advisor is triggered as a dialog box showing the Design Moment, Area of Steel Calculated, k\_value and lever arm, z value. This guides the user to make the best of choice decision when picking reinforcement from the steel table. For example, when the button with 943 is clicked, area of Steel provided immediately appears in the text box as 943 while text box in front of Number of steel label reveal 3 and text box in front of Bar size provided label divulge 20. The Black Monitor at the extreme right hand side of the visRCD Table Advisor Interface quickly alerts us that we are on the right path since Area provided is greater than Area calculated. The alert is revealed in blue colour otherwise, it will be revealed in Red colour. Without leaving the interface (Figure 4), we can check for Minimum and Maximum Area of Steel and deflection by clicking the appropriate button, and then the revelation is monitored in the black box. Once we are okay, 'Accept' button is triggered while the data is transferred back to the main program for further use. Thereafter, the interface becomes invisible.

## VISUAL BASIC CODE BEHIND DEFLECTION:

```
Private Sub CheckDeflection_Click_
(ByVal sender As System.Object, ByVal e As System.EventArgs) _
Handles CheckDeflection.Click
On Error GoTo userError
```



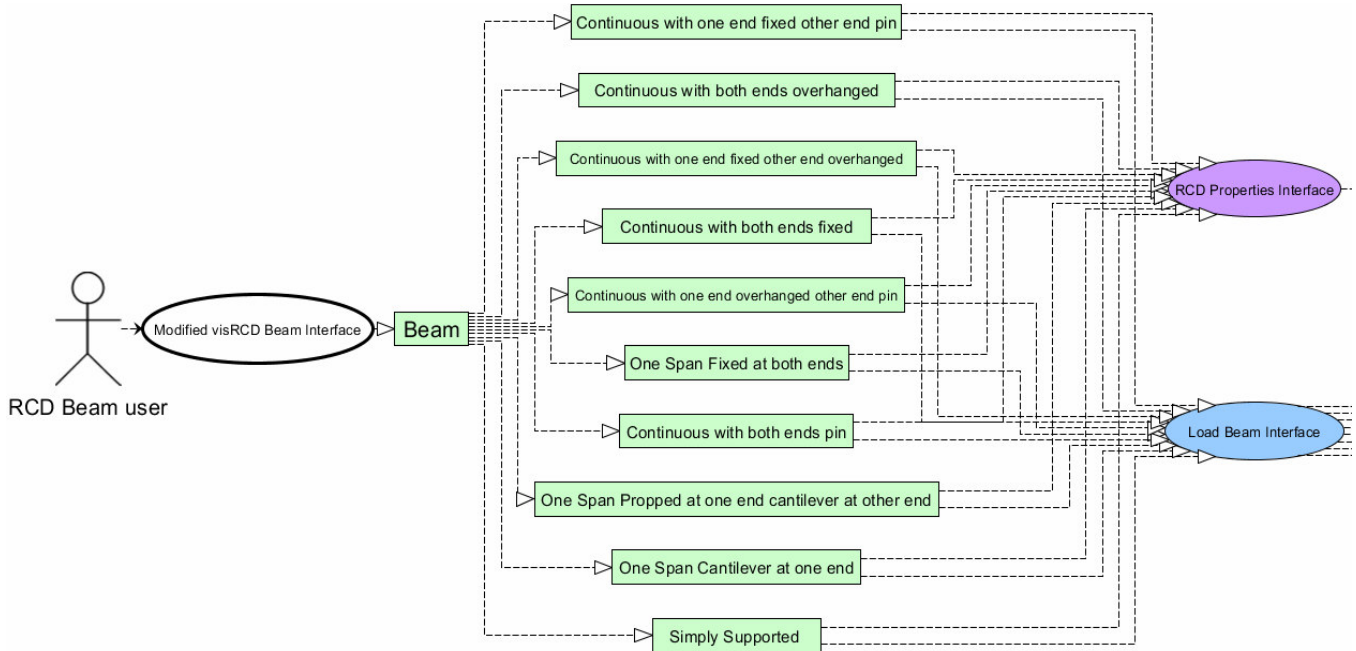


Figure 2a. UML diagram for RCD Beam interface showing RCD table advisor.

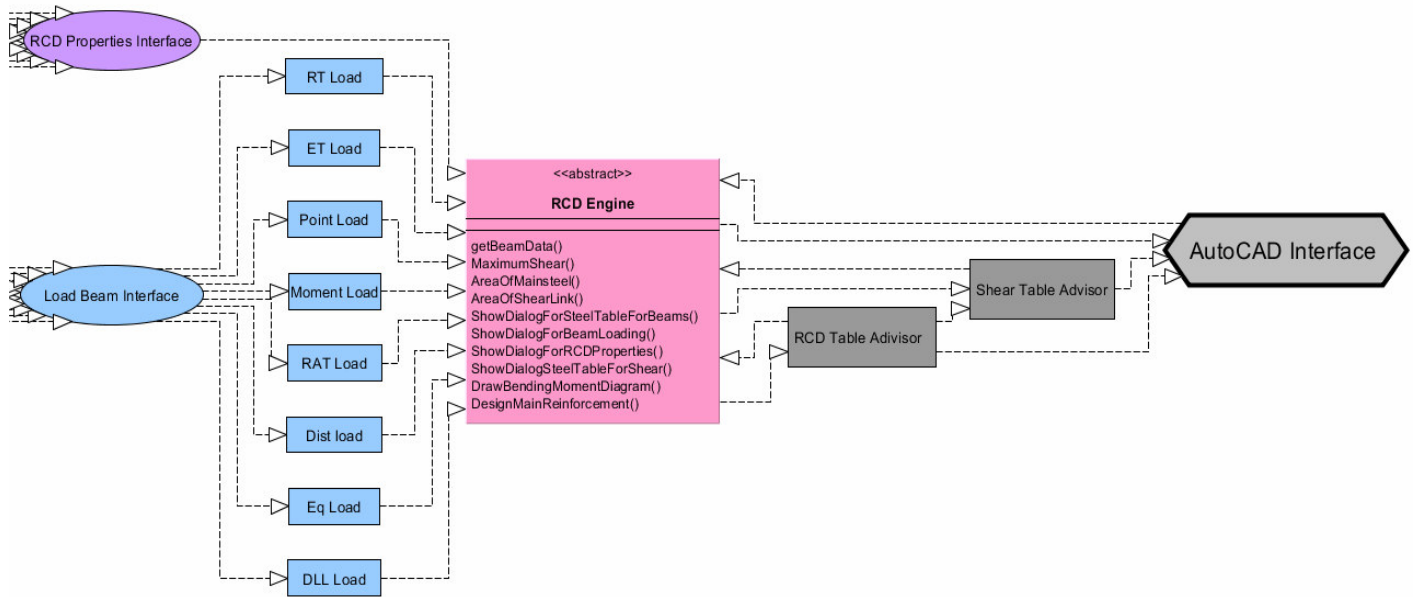


Figure 2b: UML diagram for RCD beam interface showing RCD table advisor.

```

spanEffectiveDepthRatio = 20
TxtBeamDepth.Text = TxtBeamHeight.Text -
Me.BarSizeProvided.Text / 2 -
TxtLinks.Text - TxtConcreteCover.Text
Dim ServiceStress As Single =
2 / 3 * TxtSteelGrade.Text *
Me.AreaCalculated.Text / Me.AreaProvided.Text
Dim mm As Single
Dim ModificationFactorForTensionSteel As Single
    
```

```

Dim ActualDepthRequired As Single
Dim Fs As Single
If ServiceStress = 477 Then
Fs = 477
Fs = 477 - ServiceStress
End If
mm = (Me.Moment.Text * 10 ^ 6) /
(RcdProperties.TxtBeamWidth.Text * TxtBeamDepth.Text ^ 2)
mm = mm + 0.9
    
```

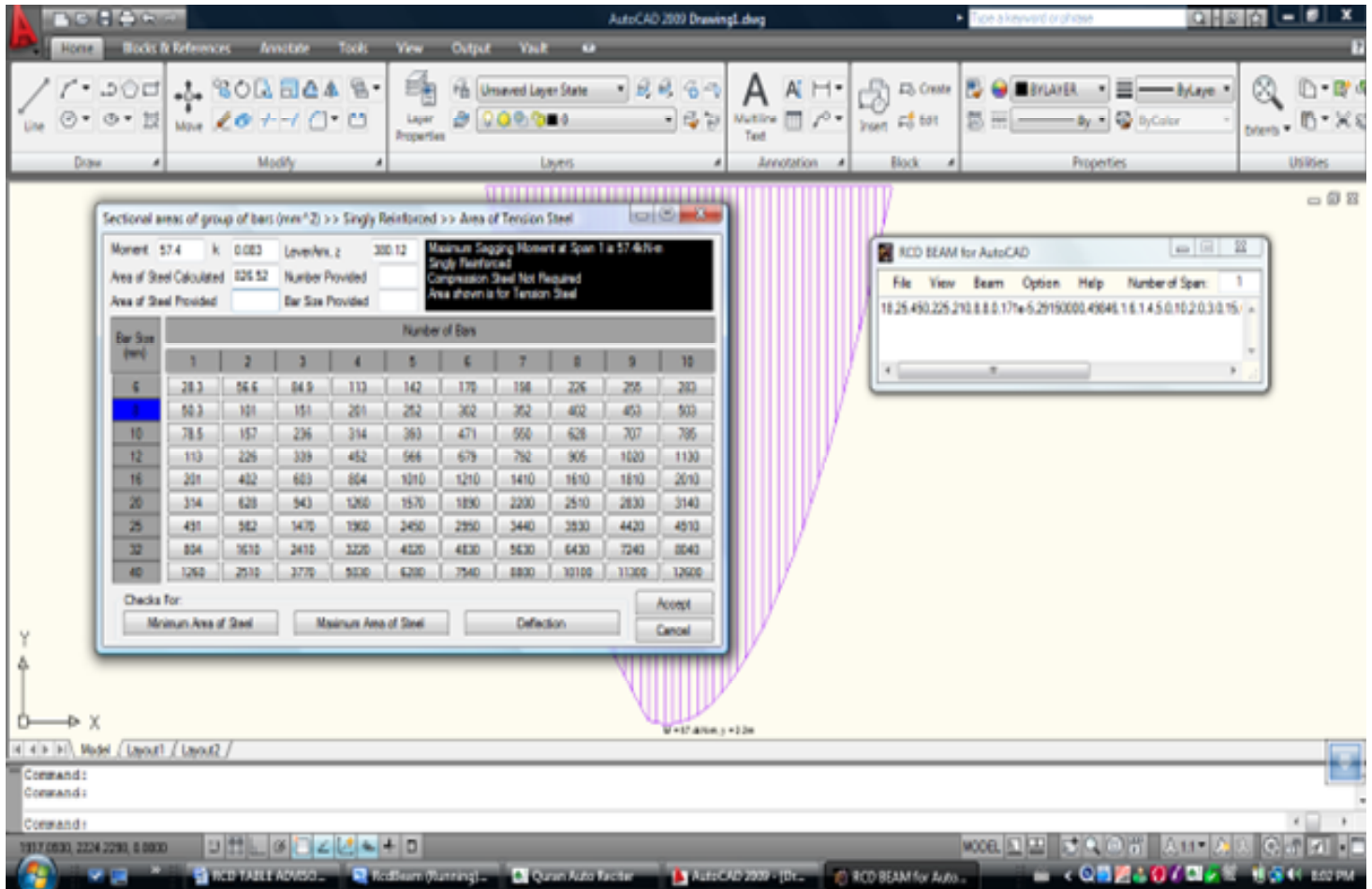


Figure 3. Modified AutoCAD environment and RCD beam Interface displaying VisRCD table advisor and bending moment diagram.

Sectional areas of group of bars (mm<sup>2</sup>) >> Singly Reinforced >> Area of Tension Steel

Moment 57.4 k 0.083 LeverAm, z 380.12 Deflection criteria is satisfied  
 Area of Steel Calculated 826.52 Number Provided 3 Beam Depth = 407  
 Area of Steel Provided 943 Bar Size Provided 20 Actual Depth Required = 142.05

Bar Size (mm)	Number of Bars									
	1	2	3	4	5	6	7	8	9	10
6	28.3	56.6	84.9	113	142	170	198	226	255	283
8	50.3	101	151	201	252	302	352	402	453	503
10	78.5	157	236	314	393	471	550	628	707	785
12	113	226	339	452	566	679	792	905	1020	1130
16	201	402	603	804	1010	1210	1410	1610	1810	2010
20	314	628	943	1260	1570	1890	2200	2510	2830	3140
25	491	982	1470	1960	2450	2950	3440	3930	4420	4910
32	804	1610	2410	3220	4020	4830	5630	6430	7240	8040
40	1260	2510	3770	5030	6280	7540	8800	10100	11300	12600

Checks For: Minimum Area of Steel Maximum Area of Steel Deflection Accept Cancel

Figure 4. VisRCD table advisor for main and distribution steel as decision support system.



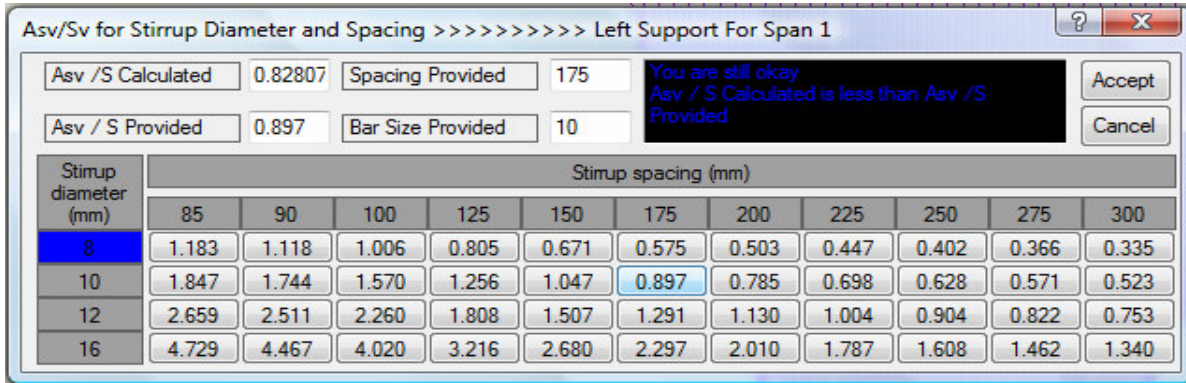


Figure 5. VisRCD table advisor for shear steel as decision support system.

```

mm = mm * 120
ModificationFactorForTensionSteel = 0.55 + Fs / mm
If ModificationFactorForTensionSteel > 2 Then _
ModificationFactorForTensionSteel = 2
ActualDepthRequired = _
(BeamLoading.TxtSpanLength.Text * 1000) / _
(ModificationFactorForTensionSteel * spanEffectiveDepthRatio)
Else
If ActualDepthRequired <= TxtBeamDepth.Text Then
MsgAlert.Text = _
"Deflection criteria is satisfied" & vbCrLf & _
"Beam Depth = " & TxtBeamDepth.Text & vbCrLf & _

"Actual Depth Required = " & _
Math.Round(ActualDepthRequired, 2)
MsgAlert.ForeColor = Color.Blue
Else
MsgAlert.Text = _
"Deflection criteria is not met" & vbCrLf & _

"Beam Depth = " & TxtBeamDepth.Text & vbCrLf & _
"Actual Depth Required = " & _
Math.Round(ActualDepthRequired, 2)
MsgAlert.ForeColor = Color.Red
End If
Exit Sub
userError:
MsgBox("Error due to mis use or lack _
of understanding of RCD by the user")
End Sub
    
```

We followed the same procedure to pick shear link bar from shear table, Asv/S calculated is automatically revealed which guide us into picking 10 Y bar at 175 mm spacing. The visRCD Table Advisor for shear table is shown in Figure 5.

**RESULT**

**Usability study**

We carried out a study to compare the modified SSRCBS tool with the old SSRCBS tool. Both were run on PC using mouse and key board with 32bit colour 1366 by 768 resolution display, 4gig RAM, 64bit Operating System with Window Vista Home Premium Edition.

In order to be gender sensitive, seven male and five female subjects were carefully chosen among RCD analysts to evaluate the modified tool. Following brief tutorials to acquaint the subjects with the software, each subject performed 5 tasks using the software. Necessarily, the order of software used and the task set for the software were counterbalanced to minimize the effects of training or the possibility of one task set being slightly more difficult than another. A limit of five minutes was set for the completion of each task, since this deadline seemed consistent with a user's expectations of being able to discover information from the tool.

The typical tasks were:

- Set up SSRCBS environment.
- Load SSRCBS tool.
- Process input.
- Analyze beam.
- Design beam using RCD table advisor.

**Observations**

What aspects of the new tool are of principal interest and should be our concern? An obvious performance measure is the time needed to complete a task. Another is the success in completing a task. More subjective is the user's satisfaction and preference, though this was then transformed by the user to quantitative value (1 = very difficult, 5 = very easy) for purposes of statistical analysis.

Finally, in the course of observing the progress of any experiment, usability issues always arise and indeed, point the way to potentially useful redesigns and research.

**Task completion times**

Statistical analysis revealed that the significance of time was borderline. It was also found that as the tasks

became more complex the visRCD Table Advisor tool advantage increased because users were prompted to take a decisive decision for the design to continue.

### Task success

Tasks were completed successfully and significantly more often using modified tool (on average, an 80% success rate versus 75% for the unmodified SSRCBS tool. The more difficult and ambiguous tasks were successfully completed more often with modified tool. This was primarily because the user had the ability to get and in return provide all the information across a particular time span into one view in order to answer the question. The unmodified SSRCBS tool User was confined to pre-determined answers without option for alteration.

### Satisfaction and preference

Modified tool was rated higher than the unmodified SSRCBS tool in terms of task-by-task satisfaction, though the significance of this result was also borderline. Modified tool was also rated higher in terms of users understanding of the logic behind RCD. Participants observed that the terminology was cleared and precise, they also believe that the amount of screen explanation was adequate for performing the tasks.

### USABILITY

We received good design feedback from participants suggesting how best to move towards redesign. For example, many users disliked the black background colour of the textbox for message alert. They wanted a white background with fore-colour in green indicating success while red fore-colour to indicate danger or failure. They also wanted to see all the messages sent to the message alert textbox to be appended for ease of review. Users expressed strong concerns about the desirability of entering the design moment directly as an option with 'area of steel calculated' automatically generated.

It is rare to encounter a clear-cut expression of preference, or the reverse, for a thoroughly explored innovative interface, and the outcome of an overall satisfaction questionnaire and briefing completed by participants is no exception. Responses to the questionnaire revealed no significant differences, though users preferred the modified tool, three abstained, saying they wanted features of both with our new innovation tagged as manual while the old tagged as wizard, and two participants chose the old SSRCBS tool. It was also clear that a frequent reason cited for choosing the old tool was the participants' familiarity with the tool. Again, as with the

development of many innovative interfaces, several areas of future work were identified. Inevitably users requested a long list of desirable features and these must be examined to see how they would affect users without jeopardizing ease of use for the novice. It was also recognized that studies must be carried out on how to incorporate our tool into hand-held devices using pens and touch-screens rather than the mice and keyboards that necessarily had to be employed in the reported studies.

### CONTRIBUTION TO KNOWLEDGE

- The analysis led to the development of a process model for visRCD Table Advisor and related visualization needs.
- The support necessary for responding to failure extends visRCD table Advisor beyond data manipulation and viewing. The ability to save views, print views, manually manipulating views, keep histories of exploration and activity, and annotating failure alert, all help analysts document and report incidents.
- This work will help design, and as well assist construction engineers, non-technical personnel and students that studies civil/structural engineering to better visualize the sequences of operations, and design details of reinforced concrete structures, and make them better equipped to design, manage, estimate and schedule more effectively.
- The visualization techniques will also be a valuable aid in the development of an effective self-directed tool for open learning via the web and with little effort (training) visualization will make the mediocre become an expert in an unfamiliar terrain of Structural/Civil Engineering.
- The overall ease with which a user will apply this program to everyday beam analysis and design tasks by entering parameters and instantaneously receiving/visualizing/interacting with the results in an understandable manner will enable a great time and cost saving, accuracy and hence, an optimized design.

### LIMITATIONS

The visRCD Table Advisor tool cannot read user's mind. User must provide data partly based on the advice generated by the tool and to some extent, based on their intuition. For example, when different users worked independent of each other, the tool may generate different output thus buttressing the fact that "there is no unique solution to any engineering problem", but a meaningful decision is made based on the advice generated by the tool which solves a unique problem.

### Conclusion

We are still in the discovery phase of information visualization as applicable to RCD, although this phase

will not last for long. In the next few years, the wild inventions that are now being implemented will become standardized. The novel RCD visualization systems of today's laboratory will become cultural artefacts and everyday tools of the RCD professionals. Indeed, visualization plays a pivotal role in the VisRCD Table Advisor process. It provides an excellent platform for human-computer interaction by narrowing the gap between human and computer during RCD analysis and design, and consequently tightens the three-step iterative loop of data exploration, formulation and testing. The proposed two-tier strategy for the integration of knowledge discovery and visualization emphasizes the strategic role of visualization as a front-end technique in the visRCD Table Advisor process.

During data processing, visualization serves as a front-end data mining tool, providing first-level data exploration and analysis for the RCD analysts, whose output serves as input for further RCD analysis. Through visualization, we are able to combine the strategies of human participation effectively with domain knowledge guidance, in a unified manner, enhancing the visRCD Table Advisor process, by identifying and formalizing the role of visualization in the visRCD Table Advisor process. Future RCD work will incorporate visRCD Table Advisor process systems as an option to the end users to pick reinforcement manually.

This will facilitate and incorporate visualization as a necessary key component in enabling appropriate human intervention. Participants considered the tool a visionary persuasive device that gives the right answers, the one that can give the best delivery time and product quality at the lowest possible cost. The tool will also improve user's ability to maintain a sense of where they are and where they hope to be. We believe that when we do it this way which is the right way, we shall hit the highway.

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