CIVIL AND CONSTRUCTION ENGINEERING AND ETHICS

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INTRODUCTION

Mankind will always need facilities and structures to maintain and improve the current way of life. Thus, civil engineering is paramount to meeting this objective. Civil engineering projects include many areas, such as environmental, geotechnical, structural, transportation, and water resources. Whereas civil engineering focuses on the design of these types of projects, construction engineering and management focuses on the realization and manifestation of these designs.

Civil and construction engineering serves the public by building the physical environment. Therefore, the health, safety, and welfare of human life and the environment are of utmost concern. To meet this overwhelming responsibility, many moral and ethical decisions must be made.

Although civil and construction engineering research does not involve direct testing on humans or animals, Martin and Schinzinger (1989) submit that the very practice of engineering is akin to a social experiment in which humans, as clients and the public, are the subjects. As subjects, clients and the public have the right to know the risks to which they are exposed. As researchers, engineers must respect the rights of clients and the public and not succumb to pressures from managers and supervisors to violate their conscience. Although managers and supervisors have the authority to guide engineering work, they must allow the engineers that they supervise the freedom to satisfy their moral convictions. The purpose of this paper is to address the ethical issues faced by the civil and construction engineering profession.

Question 1

What is the most important concern of the civil and construction engineering profession?

- ***a. The health, safety, and welfare of human life and the environment***
- *b. Providing quality engineering services at a fair price*
- *c. Managing clients desires and expectations*
- *d. Providing a good work environment for employees*

Question 2

*Which of the following concepts does **not** apply to the practice of engineering as a social experiment?*

- *a. Engineers are viewed as researchers and the public is viewed as subjects*
- *b. The public has a right to be informed of the risks that they are exposed to*
- *c. Engineers must have the freedom to satisfy their moral convictions*
- ***d. Engineering managers must ensure that employees have the same moral convictions as the firm***

ETHICAL THEORIES

According to Koehn (1993), ethical theories may be used to make rational decisions. Knowledge of ethical theories can clarify moral assumptions and provide a framework for defending ethical views. Knowledge of ethical theories may also be used to help identify moral issues and raise awareness of alternative moral perspectives. Furthermore, knowledge of ethical theories can help engineers confront moral dilemmas and prevent them from becoming problems.

Comstock (2006) has summarized the following ethical theories that engineers may use in moral decision-making:

1. Egoism
2. Virtue Theory
3. Utilitarianism
4. Moral Rights

Egoism

The theory of egoism states that each person should act ethically because it is in their own best interest. Egoism accounts for the fact that each person has his own particular interests. If a person does not act ethically, then he is probably harming himself because unethical behavior is not in his best interest. Therefore, egoists will always focus on their ultimate goals and do whatever is necessary to attain them. The primary weakness with egoism is that it is prejudiced towards an individual's self-interests.

Virtue Theory

Virtue theory examines what is the ultimate good. The ultimate good entails not only what is good for the individual but what is good for the entire community of the individual. Virtue theorists maintain that the individual should exhibit behavior that the community considers to be virtuous. In other words, the individual should always observe the rules of the community. The primary weakness of virtue theory is that it is difficult to criticize the virtues of the individual's community.

Utilitarianism

Utilitarianism states that the individual should do what is in the best interest of all people, even those outside of the individual's community. By doing so, the best consequences for everyone are maximized. Instead of maximizing the benefits of the community alone, the individual must consider equally the similar interests of others that are affected by the individual's actions. In other words, a person must give equal consideration to others that are affected by his actions with the intent of good consequences prevailing over bad consequences. The primary weakness of utilitarianism is that it seems to devalue the interests of the people that are closest to the individual.

Moral Rights

Similar to utilitarianism, the theory of moral rights is focused on all people. However, moral rights proponents are concerned with protecting the integrity of individuals rather than maximizing benefits of the community. Moral rights theory is also similar to utilitarianism in that it is impartial because the theory claims that all people deserve equal treatment. The difference between moral rights theory and utilitarianism is that the moral rights theory does not permit individuals to be used to achieve the greater good. In other words, it is never acceptable to hurt an individual to provide benefits for others regardless of how many benefits may be provided. The primary weakness of moral rights theory is that it is difficult to justify the existence of moral rights.

Question 3

*Which of the following would **not** be considered a benefit of knowledge of ethical theories?*

a. *Identifying moral issues and raise awareness of alternative moral perspectives*
b. *Clarifying moral assumptions and provide a framework for defending ethical views*
c. ***Influencing others to accept the moral perspectives of management***
d. *Confronting moral dilemmas to help avoid problems*

Question 4

As a civil engineer, Bob believes it is in his own best interest to act ethically because it will help him to remain gainfully employed. Which ethical theory is Bob exhibiting?

a. ***Egoism***
b. *Virtue Theory*
c. *Utilitarianism*
d. *Moral Rights*

Question 5

Bob has the opportunity to relocate to another city and become involved in a large project that will have far-reaching benefits to his new community and the surrounding area. However, his family does not believe that it is in their best interest to move from their current home and Bob's friends will miss him if he moves. This situation represents which ethical theory?

a. *Egoism*
b. *Virtue Theory*
c. ***Utilitarianism***
d. *Moral Rights*

Question 6

Civil and construction engineers not only interact with society as professionals, but also as individuals. Therefore, when they act ethically they not only benefit society but they benefit themselves also. Which ethical theory does this represent?

a. *Egoism*
b. ***Virtue Theory***
c. *Utilitarianism*
d. *Moral Rights*

Question 7

In civil and construction engineering, some projects may provide benefits for some yet come at a cost of lost benefits for others. For example, a new highway will provide many benefits for the traveling public but its construction will begrudgingly displace several families from their homes. Which ethical theory is described by this scenario?

a. *Egoism*
b. *Virtue Theory*
c. *Utilitarianism*
d. ***Moral Rights***

ETHICAL ISSUES IN ENGINEERING PRACTICE

In addition to technical issues, engineers are required to deal with ethical issues that affect the health, safety, and welfare of the general public. Not only are ethical standards required, but engineers have found that ethical conduct typically improves business operations. Therefore, engineers must closely examine the ethical issues that they are faced with on a day-to-day basis.

Types of Issues

A study by Koehn (1993) identified many of the ethical issues that engineers are faced with. These issues include the following:

- Technical incompetence or misrepresentation of competence
- Conflicts of interest
- Discrimination, favoritism, or harassment
- Misuse of company or client resources
- Failure to protect public health, safety, or welfare
- Improper relations with clients or contractors
- Improper political or community involvement
- Mishandling sensitive information
- Failure to reconcile employee concerns
- Alcohol and drug abuse
- Failure to protect the environment
- Poor quality control or quality of work

By examining and addressing these issues, engineers not only are acting responsibly and ethically but they are most likely improving their business operations. Thus, it is important for engineers to promote ethics within the industry.

Question 8

Most engineers have found that acting ethically typically improves business operations.

a. True

b. False

Promoting Ethics

Obviously, basic ethical standards are required in the field of engineering; integrity is required at the individual, management, and organizational levels. Therefore, ethics and integrity must be emphasized to all members and all segments of engineering. Schultz (1992) offers the following elements that may be used to promote engineering ethics:

1. Clear communication of the organization's values and principles
2. Organizational leaders "walk their talk"
3. Candor, an environment for open discussions without fear of embarrassment or retribution
4. Emphasis on total quality principles and expectations
5. Trust, assuming people will do what they say they will
6. Tolerating honest mistakes but not cover-ups

7. Fairness, rules apply equally to all
8. Minimize temptation to do something they believe is wrong
9. Respect for the dignity of the individual
10. Recognizing and rewarding people for the correct ethical reasons, e.g. being concerned about both methods and results
11. Promoting a strong feeling of team involvement and employee empowerment in goal setting and decision making
12. Neither tolerating nor ignoring unethical actions

By applying these basic concepts, engineers not only can improve business operations but society benefits from the integrity and ethical behavior of engineers.

Question 9

Acting ethically typically provides which of the following benefits to society and the civil engineering and construction firm?

a. The health, safety, and welfare of the public and the environment are protected
b. The business operations of the firm typically improve
c. Engineers are allowed to address their moral convictions
d. All of the above

CODES OF ETHICS

As stated previously, basic ethical standards are necessary for engineering. These standards are often outlined in a professional code of ethics. Vesilind (1995) argues that there are three objectives for professional codes of ethics:

1. Codes enhance the image of the profession
2. Codes clarify the rules of conduct within the profession
3. Codes promote the public good

The first objective of codes of ethics is to position the profession in a positive light. For example, most engineering codes of ethics state the primary concern of engineers is the public welfare. This implies that the main purpose of engineering is service to the public.

The second objective of codes of ethics is to clearly state the rules of conduct that each member of the profession is expected to follow. For example, engineers are only allowed to advertise their services in a modest and dignified manner. This benefits everyone because excessive advertising costs are eliminated and the image of the profession is enhanced.

The third objective of codes of ethics is to ensure that professionals make responsible decisions that benefit the public. These codes should offer guidance to engineers and other professionals for making difficult decisions that are frequently encountered.

The American Society of Civil Engineers (ASCE) code of ethics meets these objectives. The fundamental principles of the code state the following:

> Engineers uphold and advance the integrity, honor and dignity of the engineering profession by:

1. using their knowledge and skill for the enhancement of human welfare and the environment;
2. being honest and impartial and serving with fidelity the public, their employers and clients;
3. striving to increase the competence and prestige of the engineering profession; and
4. supporting the professional and technical societies in their disciplines

Not only does the ASCE Code of Ethics promote human welfare, the code also provides guidelines for how engineers are to treat each other. When practiced according to these principles, civil engineering has the ability to have a positive impact on the natural and built environment. A complete copy of the ASCE Code of Ethics is included in Appendix A and the code may also be found at www.asce.org/inside/codeofethics/cfm.

Question 10

*Which of the following is **not** an objective of codes of ethics?*

a. Portray the profession positively
b. Establish rules of conduct within the profession
c. Promote the public good
d. Ensure that engineering firms make a profit

CASE STUDIES

Perhaps the best way to explore the practicality of ethics in civil and construction engineering is to examine the case studies of events that have actually happened. The first case study examines the collapse of the Kansas City Hyatt Regency walkway due to a poor ethical decision. The second case study examines how a potential disaster was avoided at the New York Citicorp tower because of a good ethical decision.

Kansas City Hyatt Regency Walkway Collapse

In 1981, a suspended walkway in the atrium of the Kansas City Hyatt Regency collapsed and killed 114 people and injured 185 more. In terms of loss of life, this was the worst structural disaster in the United States. A process that began with the approval of a simple shop drawing, ended as one of the greatest tragedies in American history.

The walkway was originally designed to be supported by a box beam suspended by a continuous hanger rod through the box beam. During the process of detailing this connection, it was questioned whether the hanger rod needed to be continuous. After a telephone conversation between the structural engineer, the fabricator, and the detailer, it was decided that the continuous hanger rod could be replaced by two interrupted rods for ease of installation. A comparison of the two connections is shown in Figure 1.

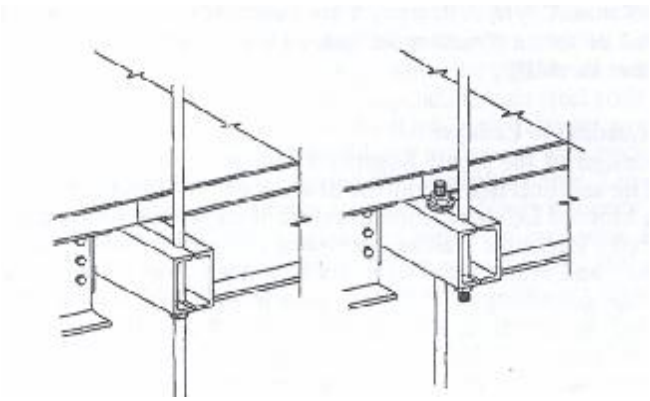

Figure 1. Comparison of Continuous and Interrupted Hanger Rod Details [Courtesy National Institute of Standards and Technology (Marshall et al. 1982)]

The connection details were prepared using the two interrupted rods connection and the connection was fabricated according to this detail. The problem was that the structural engineer never performed any additional calculations to check the adequacy of the new two rod connection. Therefore, the structural engineer did not realize that the load on this connection had been doubled due to the new design. The new two interrupted rod connection was not adequate to support the imposed loads. The walkway collapsed approximately one year after the hotel opened (Roddis 1993).

After an intensive investigation, the Missouri licensing board and the Missouri Court of Appeals concluded that the design engineers were responsible for the disaster. The engineers did not recognize the difference between their original design and the revised design suggested by the contractor, although the engineers acknowledged reviewing the revised design. The principal and the project manager of the engineering firm were held personally responsible and they had their licenses revoked. Patrick McLarney, the attorney that represented the Missouri licensing board, summed up the situation with the following quote:

> "It wasn't a matter of doing something wrong, they just never did it at all. Nobody ever did any calculations to figure out whether or not the particular connection that held the skywalks up would work. It got built without anybody ever figuring out if it would be strong enough. It just slipped through the cracks" (Levy and Salvadori 2002).

Question 11

In the Hyatt Regency case study, which of the following concepts best describes the reason for the collapse?

a. The engineers lacked technical competence
b. The engineers accepted a change in the original design without a thorough review
c. The fabricators made the support differently to save money
d. The contractors changed the support to make the installation easier

New York Citicorp Tower

William LeMessurier, one of the nation's most prominent structural engineers, was the design and construction consultant on the Citicorp headquarters skyscraper in New York which was completed in 1977. The following year, a college student who had studied the design pointed out a possible deficiency in the design of the building. After careful review, LeMessurier concluded that the building was indeed structurally deficient. He was faced with an ethical dilemma of professional responsibility in which he had to notify everyone associated with the tower of the structural problem and request their cooperation in repairing it.

In June of 1978, about a year after the Citicorp tower had been completed, LeMessurier received a telephone call from a college student. The student and his professor had been studying the design of the Citicorp tower and agreed that some of the building's critical supports had been placed in the wrong location. Although LeMessurier thought he had satisfied the questions from the student and the professor, he decided to take a closer look at the design of the building. It was during this review that LeMessurier performed additional calculations and discovered that stresses in some of the members increased by 40 percent under a particular wind load. LeMessurier became concerned that the Citicorp tower could actually collapse during a major storm, such as a hurricane.

To prevent a disaster, LeMessurier knew he had to take action. He had to notify everyone that was involved with the building, including the owners, the contractors, and city officials. Meteorological experts were even retained to provide notification of severe weather. Furthermore, LeMessurier took the responsibility of notifying the news media of the situation so that the general public would be informed.

Repairs on the building began in September 1978 and were completed the next month. Although elaborate evacuation plans had been developed in case a storm occurred before the repairs were completed, they were not needed. When the repairs were completed, the building exceeded its original factor of safety.

Obviously, LeMessurier feared for his professional reputation and his career as an engineer. However, he did not allow these worries or any self-preserving impulses distract him from his moral obligation of protecting the public and human welfare. In fact, the way LeMessurier handled this situation increased his reputation as a competent and forthright engineer. It even prompted his liability insurance company to lower the rates on his premiums (Online Ethics 2005).

Question 12

Acting ethically often improves business operations. How was LeMessurier's business operations improved after the Citicorp project?

a. His image as a competent engineer actually increased
b. He was viewed as a forthright engineer which improved his reputation
c. His liability insurance lowered his premiums
d. All of the above

CONCLUSION

The New York Citicorp tower project is an example of the proper way to handle a professional engineering dilemma; the Kansas City Hyatt Regency project is an example of how not to handle a professional engineering dilemma. The Citicorp project engineers detected a problem, performed an analysis, informed all necessary parties, and implemented a solution. The Hyatt Regency engineers neglected their responsibility and did nothing, assuming that the modification would be sufficient. Clearly, the differences in these two decisions were catastrophic.

Civil and construction engineers are required to make decisions on a daily basis that involve the health, safety, and welfare of the general public. These decisions are often related to ethical issues; therefore, ethics should be promoted within the engineering industry and academics. Codes of ethics, such as the ASCE Code of Ethics provide a guideline for engineers to use. Furthermore, ethical behavior not only protects the public but it tends to improve business operations.

ACKNOWLEDGEMENT

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APPENDIX A: ASCE CODE OF ETHICS

Fundamental Principle

Engineers uphold and advance the integrity, honor and dignity of the engineering profession by:

1. using their knowledge and skill for the enhancement of human welfare and the environment;
2. being honest and impartial and serving with fidelity the public, their employers and clients;
3. striving to increase the competence and prestige of the engineering profession; and
4. supporting the professional and technical societies of their disciplines.

Fundamental Canons

1. Engineers shall hold paramount the safety, health and welfare of the public and shall strive to comply with the principles of sustainable development [3] in the performance of their professional duties.
2. Engineers shall perform services only in areas of their competence.
3. Engineers shall issue public statements only in an objective and truthful manner.
4. Engineers shall act in professional matters for each employer or client as faithful agents or trustees, and shall avoid conflicts of interest.
5. Engineers shall build their professional reputation on the merit of their services and shall not compete unfairly with others.
6. Engineers shall act in such a manner as to uphold and enhance the honor, integrity, and dignity of the engineering profession and shall act with zero-tolerance for bribery, fraud, and corruption.
7. Engineers shall continue their professional development throughout their careers, and shall provide opportunities for the professional development of those engineers under their supervision.

Guidelines to Practice Under the Fundamental Canons of Ethics

CANON 1

Engineers shall hold paramount the safety, health and welfare of the public and shall strive to comply with the principles of sustainable development in the performance of their professional duties.

1. Engineers shall recognize that the lives, safety, health and welfare of the general public are dependent upon engineering judgments, decisions and practices incorporated into structures, machines, products, processes and devices.
2. Engineers shall approve or seal only those design documents, reviewed or prepared by them, which are determined to be safe for public health and welfare in conformity with accepted engineering standards.
3. Engineers whose professional judgment is overruled under circumstances where the safety, health and welfare of the public are endangered, or the principles of sustainable development ignored, shall inform their clients or employers of the possible consequences.

4. Engineers who have knowledge or reason to believe that another person or firm may be in violation of any of the provisions of Canon 1 shall present such information to the proper authority in writing and shall cooperate with the proper authority in furnishing such further information or assistance as may be required.
5. Engineers should seek opportunities to be of constructive service in civic affairs and work for the advancement of the safety, health and well-being of their communities, and the protection of the environment through the practice of sustainable development.
6. Engineers should be committed to improving the environment by adherence to the principles of sustainable development so as to enhance the quality of life of the general public.

CANON 2

Engineers shall perform services only in areas of their competence.

1. Engineers shall undertake to perform engineering assignments only when qualified by education or experience in the technical field of engineering involved.
2. Engineers may accept an assignment requiring education or experience outside of their own fields of competence, provided their services are restricted to those phases of the project in which they are qualified. All other phases of such project shall be performed by qualified associates, consultants, or employees.
3. Engineers shall not affix their signatures or seals to any engineering plan or document dealing with subject matter in which they lack competence by virtue of education or experience or to any such plan or document not reviewed or prepared under their supervisory control.

CANON 3

Engineers shall issue public statements only in an objective and truthful manner.

1. Engineers should endeavor to extend the public knowledge of engineering and sustainable development, and shall not participate in the dissemination of untrue, unfair or exaggerated statements regarding engineering.
2. Engineers shall be objective and truthful in professional reports, statements, or testimony. They shall include all relevant and pertinent information in such reports, statements, or testimony.
3. Engineers, when serving as expert witnesses, shall express an engineering opinion only when it is founded upon adequate knowledge of the facts, upon a background of technical competence, and upon honest conviction.
4. Engineers shall issue no statements, criticisms, or arguments on engineering matters which are inspired or paid for by interested parties, unless they indicate on whose behalf the statements are made.
5. Engineers shall be dignified and modest in explaining their work and merit, and will avoid any act tending to promote their own interests at the expense of the integrity, honor and dignity of the profession.

CANON 4

Engineers shall act in professional matters for each employer or client as faithful agents or trustees, and shall avoid conflicts of interest.

1. Engineers shall avoid all known or potential conflicts of interest with their employers or clients and shall promptly inform their employers or clients of any business association, interests, or circumstances which could influence their judgment or the quality of their services.
2. Engineers shall not accept compensation from more than one party for services on the same project, or for services pertaining to the same project, unless the circumstances are fully disclosed to and agreed to, by all interested parties.
3. Engineers shall not solicit or accept gratuities, directly or indirectly, from contractors, their agents, or other parties dealing with their clients or employers in connection with work for which they are responsible.
4. Engineers in public service as members, advisors, or employees of a governmental body or department shall not participate in considerations or actions with respect to services solicited or provided by them or their organization in private or public engineering practice.
5. Engineers shall advise their employers or clients when, as a result of their studies, they believe a project will not be successful.
6. Engineers shall not use confidential information coming to them in the course of their assignments as a means of making personal profit if such action is adverse to the interests of their clients, employers or the public.
7. Engineers shall not accept professional employment outside of their regular work or interest without the knowledge of their employers.

CANON 5

Engineers shall build their professional reputation on the merit of their services and shall not compete unfairly with others.

1. Engineers shall not give, solicit or receive either directly or indirectly, any political contribution, gratuity, or unlawful consideration in order to secure work, exclusive of securing salaried positions through employment agencies.
2. Engineers should negotiate contracts for professional services fairly and on the basis of demonstrated competence and qualifications for the type of professional service required.
3. Engineers may request, propose or accept professional commissions on a contingent basis only under circumstances in which their professional judgments would not be compromised.
4. Engineers shall not falsify or permit misrepresentation of their academic or professional qualifications or experience.
5. Engineers shall give proper credit for engineering work to those to whom credit is due, and shall recognize the proprietary interests of others. Whenever possible, they shall name the person or persons who may be responsible for designs, inventions, writings or other accomplishments.
6. Engineers may advertise professional services in a way that does not contain misleading language or is in any other manner derogatory to the dignity of the profession. Examples of permissible advertising are as follows:

- Professional cards in recognized, dignified publications, and listings in rosters or directories published by responsible organizations, provided that the cards or listings are consistent in size and content and are in a section of the publication regularly devoted to such professional cards.
- Brochures which factually describe experience, facilities, personnel and capacity to render service, providing they are not misleading with respect to the engineer's participation in projects described.
- Display advertising in recognized dignified business and professional publications, providing it is factual and is not misleading with respect to the engineer's extent of participation in projects described.
- A statement of the engineers' names or the name of the firm and statement of the type of service posted on projects for which they render services.
- Preparation or authorization of descriptive articles for the lay or technical press, which are factual and dignified. Such articles shall not imply anything more than direct participation in the project described.
- Permission by engineers for their names to be used in commercial advertisements, such as may be published by contractors, material suppliers, etc., only by means of a modest, dignified notation acknowledging the engineers' participation in the project described. Such permission shall not include public endorsement of proprietary products.

7. Engineers shall not maliciously or falsely, directly or indirectly, injure the professional reputation, prospects, practice or employment of another engineer or indiscriminately criticize another's work.
8. Engineers shall not use equipment, supplies, laboratory or office facilities of their employers to carry on outside private practice without the consent of their employers.

CANON 6

Engineers shall act in such a manner as to uphold and enhance the honor, integrity, and dignity of the engineering profession and shall act with zero-tolerance for bribery, fraud, and corruption.

a. Engineers shall not knowingly engage in business or professional practices of a fraudulent, dishonest or unethical nature.
b. Engineers shall be scrupulously honest in their control and spending of monies, and promote effective use of resources through open, honest and impartial service with fidelity to the public, employers, associates and clients.
c. Engineers shall act with zero-tolerance for bribery, fraud, and corruption in all engineering or construction activities in which they are engaged.
d. Engineers should be especially vigilant to maintain appropriate ethical behavior where payments of gratuities or bribes are institutionalized practices.
e. Engineers should strive for transparency in the procurement and execution of projects. Transparency includes disclosure of names, addresses, purposes, and fees or commissions paid for all agents facilitating projects.
f. Engineers should encourage the use of certifications specifying zero-tolerance for bribery, fraud, and corruption in all contracts.

CANON 7

Engineers shall continue their professional development throughout their careers, and shall provide opportunities for the professional development of those engineers under their supervision.

1. Engineers should keep current in their specialty fields by engaging in professional practice, participating in continuing education courses, reading in the technical literature, and attending professional meetings and seminars.
2. Engineers should encourage their engineering employees to become registered at the earliest possible date.
3. Engineers should encourage engineering employees to attend and present papers at professional and technical society meetings.
4. Engineers shall uphold the principle of mutually satisfying relationships between employers and employees with respect to terms of employment including professional grade descriptions, salary ranges, and fringe benefits.

[1] The Society's Code of Ethics was adopted on September 2, 1914 and was most recently amended on July 23, 2006. Pursuant to the Society's Bylaws, it is the duty of every Society member to report promptly to the Committee on Professional Conduct any observed violation of the Code of Ethics.

[2] In April 1975, the ASCE Board of Direction adopted the fundamental principles of the Code of Ethics of Engineers as accepted by the Accreditation Board for Engineering and Technology, Inc. (ABET).

[3] In November 1996, the ASCE Board of Direction adopted the following definition of Sustainable Development: "Sustainable Development is the challenge of meeting human needs for natural resources, industrial products, energy, food, transportation, shelter, and effective waste management while conserving and protecting environmental quality and the natural resource base essential for future development."

APPENDIX B: NCSU RESEARCH HERO

Dr. Christopher Frey is a professor in the Department of Civil, Construction, and Environmental Engineering at North Carolina State University. Dr. Frey teaches and performs research in environmental engineering with a particular focus on air pollution. Along with his research team, Dr. Frey recently completed a project that quantified the air pollutant emissions from construction vehicles and equipment as they performed real-world tasks. Although this research was not performed directly on humans or animals, it was performed in an area that has profound effects on human health and the environment. Therefore, integrity in this research is of the utmost importance.

Dr. Frey is highly regarded in academic and professional circles as an outstanding teacher and researcher. He is the author of numerous publications, reports, and presentations in his field of study. To learn more about Dr. Frey and his research, visit his website at http://www4.ncsu.edu/~frey.